DOCUMENT RESUME

ED 271 395 SO 017 451

AUTHOR	Jacobson, Willard J.; And Others
TITLE	Analyses and Comparisons of Science Curricula in Japan and the United States.
SPONS AGENCY	Office of Educational Research and Improvement (ED), Washington, DC.
PUB DATE	86
CONTRACT	NIE-P-85-3062
NOTE	106p.; For other studies in this series on education in Japan, see SO 017 338 and SO 017 443-460.
PUB TYPE	Reports - Descriptive (141)
EDRS PRICE	MF01/PC05 Plus Postage.
DESCRIPTORS	*Comparative Education; Cross Cultural Studies; *Elementary School Science; Elementary Secondary Education; Foreign Countries; Science Instruction; Science Programs; *Science Teachers; *Secondary School Science
IDENTIFIERS	*Japan; *United States; United States Study of Education in Japan

ABSTRACT

An analysis and comparison of science education in Japan and the United States is presented. Studies in comparative science education, including the first and second International Association for the Evaluation of Educational Achievement (IEA) and the Japan and United States Cooperative Science Project, provide an empirical base for some of the analyses. The review of literature presents a guide to writings in English on science education in Japan. Similarities and differences in the structure of science education programs and a comparison of elementary and secondary programs, including earth science, physics, biology, and chemistry, are analyzed. In light of the analysis results, student achievement (both Japanese and United States) in science is discussed. Similarities and differences between teachers, teacher education, and teaching methods in both countries is examined. Science education centers, student backgrounds and expectations, sex, family size, a liking of science, future science education for students, homework, and books in the home are reviewed. Proposals for educational reform and the resulting implications for science education are examined. The study concludes with a list of questions that deserve further thought and investigation and with a 10-page bibliography. (RSL)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED271395

Analyses and Comparisons of Science Curricula in Japan and the United States

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
☑ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

By

Willard J. Jacobson
Shigekazu Takemura
Rodney L. Doran
Shigeo Kojima
Eve Humrich
Masao Miyake

A Monograph of

The International Association for the Evaluation
of Educational Achievement [IEA]

USA

Second IEA Science Study
[SISS]
UNITED STATES

IEA

Teachers College, Columbia University

SE017451

ANALYSES AND COMPARISONS OF SCIENCE EDUCATION IN JAPAN AND THE UNITED STATES

Willard J. Jacobson
National Research Coordinator
Second IEA Science Study
Teachers College, Columbia University
U.S.A.

Shigekazu Takemura
Professor of Science Education
Hiroshima University
Japan

with

Rodney L. Doran
Associate National Research Coordinator
Second IEA Science Study
State University of New York at Buffalo
U.S.A.

Shigeo Kojima
Director, Research Center
for Science Education
National Institute for
Educational Research
Japan

Eve Humrich
Research Assistant
Second IEA Science Study
Teachers College, Columbia University
U.S.A.

Masao Miyake
National Research Coordinator
Second IEA Science Study
National Institute for
Educational Research
Japan

Prepared under the auspices of the United States Studies of Education in Japan and the Center for Statistics Office of Educational Research and Improvement. Contract #NIE-P-85-3062.

© 1986

Second IEA Science Study
Teachers College, Columbia University
New York, New York 10027

The work upon which this publication is based was performed pursuant to Contract No. NIE-P-85-3062 of the National Institute of Education. It does not, however, necessarily reflect the views of that agency.

ACKNOWLEDGEMENTS

We are grateful to Daniel P. Antonoplos, Deputy Director of the United States Study of Education in Japan for the invitation to undertake this Study and the support that made it possible.

We are indebted to all those who contributed time and energy to the Second IEA Science Study. This includes students and teachers in our schools, school administrators, and those who helped administer the tests and questions and process the data.

In the United States, we are grateful to the Spencer Foundation for support of the data collection for the first phase of the Second IEA Science Study--U.S.

Considerable use has been made of the data collected in the Second IEA Science Study. We are indebted to Eugene W. Muller for his expert help in handling the U.S. data in the Second IEA Science Study.

We were honored that William Cummings reviewed our manuscript, and his penetrating comments were very helpful. The authors continue to take responsibility for their interpretations, and forbid the thought, any errors that may have "crept in."

We are deeply grateful to Janis W. Owen, whose organizational ability, word processing skills, and general dedication to the cause made it all possible.

TABLE OF CONTENTS

Page

Acknowledgements iii

List of Figures vii

Chapter I - Introduction 1

References, Chapter I. 3

Chapter II - Literature Review. 5

References, Chapter II 19

Chapter III - Science Curricula. 21

References, Chapter III. 43

Chapter IV - Student Achievement. 45

References, Chapter IV 59

Chapter V - Teachers and Teaching - Students and Learning. 61

References, Chapter V. 69

Chapter VI - Schools, Technology, and School Reform 71

References, Chapter VI 82

Chapter VII - Summary, Conclusions, and Questions 85

References, Chapter VII 91

Bibliography. 93

LIST OF FIGURES

Figure Page

1 - The Japanese School System, 1980. 22

2 - Time Devoted to Science, Japan--U.S.. 23

3 - Science Program, Japan. 24

4 - Percentage of Students in Japan Enrolled in Science Courses in Upper Secondary Schools 25

5 - Patterns of U.S. Science Education. 27

6 - Number of Teaching Hours Per Year of Science and Other Subjects in the Elementary Schools. 28

7 - Number of Teaching Hours Per Year of Science and Other Subjects in the Lower Secondary Schools 32

8 - Science and Other Subjects in the Upper Secondary Schools 35

9 - Historical Development of Science Education 42

10 - Comparisons of Science Scores of Four Populations of Japanese and American Students 48

11 - Difference in Test Performance 1970 and 1983 in Bridge Items Correct. 49

12 - Group Assessment of Logical Thinking (Percent Correct). 51

13 - The Integrated Process Skills Test II (TIPS) (Percent Correct). 53

14 - Test Performances By Sex in Percent Correct on International Core Test. 55

15 - Science Teaching and Learning Variable Correlations with Mean Score in Fifth Grade International Core Test. 56

16 - Science Teaching and Learning Variable Correlations with Mean Score on Ninth Grade International Core Test. 57

17 - Types of Teacher Certificates and Qualifications Thereof. 64

18 - Minimum Requirements for Science Teacher Preparation. 65

CHAPTER I
INTRODUCTION

This is an analysis and comparison of science education in Japan and the United States. The work is based on the assumption that we can learn from each other. There are important similarities, and it is important to learn of them. There are significant differences, and it is also advantageous to learn from them. In both countries it is hoped that these analyses and comparisons will lead to better science education for our children and young people.

There are important geographic differences. Japan is a relatively small island country, off the coast of the Asian continent. Four main islands, Hokkaido, Honshu, Shikoku, and Kyushu make up most of the country. The United States, however, is mainly a continental nation separated from other continents by the Atlantic and Pacific Oceans. Its land area is about 25 times that of Japan. Japan has few natural resources, with little mineral and energy resources and a scarcity of agricultural land. Many Japanese consider their people to be their most important resource. The United States has many natural resources, including rich energy and mineral deposits and some of the most fertile agricultural land in the world. However, many Americans would join their Japanese colleagues in saying that people are their most important resource.

There are significant demographic differences. The Japanese population is comparatively homogeneous. Almost all Japanese have similar cultural backgrounds and speak the same language. The homogeneity may be epitomized by the comments of two Japanese science educators who were engaged in a group discussion with American colleagues, "We Japanese have so much in common that we are able to communicate with each other with our eyes." The American population is very heterogeneous. All Americans or their ancestors, including the American Indian, came from somewhere else. While English is the language spoken by almost everyone, Americans tend not to have the same common culture as do many Japanese.

The Japanese have a centralized school system, while education in the U.S. is very decentralized, with many of the key educational policy decisions made by the states or communities within the states. Yet, both nations are dedicated to making education available to all of their children and young people.

Both nations view science and technology education as very important. The Japanese consider science education as a key element in their remarkable industrial and economic development. Science education has made essential contributions in the last four decades, and it will be indispensable in the future. In the United States, the case for science and technology education has been stated authoritatively by the National Science Board Commission on Precollege Education in Mathematics, Science and Technology:

> By 1995, the Nation must provide, for all its youth, a level of mathematics, science and technology education that is the finest in the world, without sacrificing the American birthright of personal choice, equity and opportunity. (1)

But, both nations can learn from each other, and this study is a systematic attempt to analyze and compare so that we may all learn.

This study is an analysis of science education in Japan and the United States. It has been undertaken by science educators in Japan and the United States. This common background in science education is of great help in communication. They also have had the experience of studying and teaching science in their respective countries, and they have considerable knowledge of science education research in their nations.

Studies in comparative science education, such as the First and Second IEA Studies in Science and the recent Japan and U.S. Cooperative Science Project, "A Study of Reasoning Skills in Junior High School Students," provide an empirical base for some of the analyses. Many other sources of information have also been used.

An attempt has been made to uncover all of the literature in English dealing with science education in Japan. This literature is listed in the "Bibliography." Some of the most important studies are reviewed in the "Literature Review." There are general works on education in Japan that have some special relevance for science education, and some of these are also included in the review of the literature.

To many science educators, "Japanese Science Curricula" will be of special interest. Analyses are made of elementary, lower secondary, and upper secondary school programs. This includes the analyses of the upper secondary courses in earth science, physics, biology, and chemistry. In some cases, these curricula are related to comparable science curricula in the United States.

How do Japanese and American students do in science? Recently, empirical studies have been carried out in both Japan and the United States, and some of the results of these studies are the base on which the discussion of science achievement in Japan and the United States is built. Also, IEA science studies were carried out in both countries in 1970 and again in 1983. Thus, it is possible to ascertain changes that have taken place in science achievement in these two countries. Of special interest is a study of reasoning skills of students in Hiroshima and the State of North Carolina. A co-author of this monograph was an investigator in that study, and some of the results are discussed in this monograph.

An area that is of great interest to many is the difference between scores in science achievement of females and males in Japan and the U.S. Of great importance are the changes in the differences in scores between females and males at different grade levels in each of the school systems. Do these differences increase or decrease as students pass through the school systems?

There are similarities and differences in teachers, methods of teaching, and teacher preparation in the two countries. The goals and some description of how teachers are prepared in the two countries is included. There are interesting differences in the ways teachers are recruited and appointed. In both countries, it is recognized that education should be a lifelong process and that in-service education for teachers is of special importance.

Schools and schooling in the two countries also have similarities and significant differences. In both countries, most young people finish the secondary school, and thus have 12 or 13 years of formal education. But, the Japanese school year is longer, and in Japan they end the school year and begin the next year before the summer holidays. Classroom groups are assigned a teacher who will continue to be their teacher in the autumn, after the summer holidays. They are given assignments to be completed over the summer, and the assigned work is read and reviewed with the student in the autumn. Most observers of Japanese education also attach great importance to the entrance examinations and the preparation for these tests. These examinations have an enormous impact upon students and their families. The "juku" cram schools apparently are a rather unique Japanese institution and are widely used by young people.

In both Japan and the U.S., education, including science education, is being subjected to searching criticisms and lively discussions. Some of the proposals for educational reform and possible implications for science education are discussed in this monograph.

REFERENCES

1. The National Science Board Commission on Precollege Education in Mathematics, Science and Technology, Educating Americans for the 21st Century, Washington, D.C.: National Science Foundation, 1983, p. v.

CHAPTER II
LITERATURE REVIEW

This literature review is intended to be a guide to writings in the English language on science education in Japan. Because the literature is intended to be of value primarily to those who operate in the English language, important literature that is available only in the Japanese language is not included. Since science education exists in schools and in a society, a few carefully selected general works on education in Japan are included. However, the emphasis in the "Review" is on science education.

This literature review is an introduction to the literature. An attempt is made to describe the information that is available in each of the items reviewed and to link the article or book to some of the questions that are being raised about Japanese science education. Some of these articles and books are also used in the next section as we analyze various characteristics of Japanese science education.

International comparisons in education, including science education, are difficult and always involve complications and assumptions that must be kept in mind. Torsten Husen, long-time chairman of the International Association for the Evaluation of Educational Achievement (IEA), in his article, "Are Standards in U.S. Schools Really Lagging Behind Those in Other Countries?" (1) has suggested that comparing the outcomes of learning in highly industrialized countries may be an attempt to compare the incomparable. However, he then goes on to suggest that such factors as the following should be considered in making educational comparisons. One factor that must be considered is the role that the central government plays in developing educational programs, evaluating students and schools, and financing and inspecting education. As we shall elaborate in this report, Japan and the United States are very different. Japan has a highly centralized system of education, and the U.S. system is very decentralized. IEA studies seem to indicate that a strong relationship exists in most countries between the "opportunity to learn" and science achievement, and the degree to which students in both Japan and the United States have opportunities to learn science will be explored in depth. Husen suggests that in highly complex, technological societies there is a contradiction between the norms of equal opportunity versus meritocracy and that the more societies depend on advanced and sophisticated technology, the more acute the dilemma becomes; this dilemma, as it arises and affects education in Japan and the United States, will be described and analyzed.

There is much to be learned from the study of Japanese education. Selective borrowing has the potential to enhance American education, but surely thoughtless replication should be avoided. Nobuo K. Shimahara in his "Japanese Education and its Implications for U.S. Education" (2) examines some of the sociological and educational factors and suggests some implications for U.S. education. Some of the sociological factors are the vertical social mobility of young people seeking the right initial job and working to advance within that workplace, the profound socioeconomic and cultural homogeneity which is a tremendous advantage in attaining cognitive quality, the generally accepted belief that formal education improves one's lot, and the all-pervasive influence of the college entrance examination system that compels students and their families to undertake prolonged preparation for these examinations. Educational factors are the intensity of the schooling where students attend school for six days a week and 240 days a year and are assigned review work for the summers. Other educational factors are the tutoring and drill schools that prepare students for examinations, the emphasis on effort rather than innate ability, the upgrading of entire classroom groups which provides an atmosphere conducive to mastery learning, and the responsibility that teachers assume for the motivation of their students. Some of the implications for U.S. education are that more attention should be given to the development of more productive work and study habits. U.S. schools should be "de-bureaucratized" so that teachers can give more attention to motivating students, consider lengthening the amount of time devoted to instruction, develop a well-defined sense of purpose of school-work, and consider the development of a national agenda for such fields as mathematics and science.

Japan has a centralized school system and the Ministry of Education, Science and Culture of the Government of Japan, in addition to providing the bulk of the resources needed to support a modern educational system, develops courses of study which indicate what should be studied in Japanese schools. Among these courses of study are Course of Study for Elementary Schools in Japan (3), Course of Study for Lower Secondary Schools in Japan (4), and Course of Study for Upper Secondary Schools in Japan (5). These courses of study contain:

1. Overall objectives. (An interesting overall objective is "...to have students realize the relationship between nature and human beings.")
2. Objectives and contents for each field. (This includes a brief outline of the content to be developed.)
3. Preparation of the teaching program and points for special consideration in teaching. (These are very brief discussions of how much time should be allotted to each of the fields and some suggestions for emphasis in teaching.)

These courses of study are relatively brief and lacking in detail in comparison with courses of study developed in U.S. school systems. But, these broad outlines are used by textbook writers and others to develop, in much greater detail, the textual materials and suggestions for teaching. A perusal of a Japanese elementary science textbook series indicates how the brief outlines in the courses of study are expanded with much greater detail with much more specific text and suggestions for teaching. Observations in Japanese schools indicate that the teachers, using textbooks and other educational materials, go far beyond the outlines in the courses of study. (See Chapter III for more detail).

The acronym for the Ministry of Education, Science and Culture is MOMBUSHO, and in a colorfully designed pamphlet entitled Mombusho (6), the various responsibilities of the Ministry and the resources it devotes to various areas are listed. In this publication, the number of credits required in the various subjects in the Upper Secondary School is given. In science, 22 credit hours are provided (4 credit hours are required and 18 credit hours are elective). One credit consists of 35 unit hours in a school year and a unit hour is 50 minutes of teaching (p. 23). Physics, chemistry, biology, and earth science are each taken for four credit hours. If one of these subjects is taken for a year, it would call for 140 unit hours of instruction. In Mombusho, there are also descriptions of the scientific and cultural activities in the Ministry.

There are books that, while not dealing specifically with Japanese science education, provide a description of the Japanese educational system in general and a discussion of the historical background of Japanese education. The Ministry of Education, Science and Culture, in Japan's Modern Educational System - A History of the First Hundred Years (7) devotes considerable attention to the history of the development of education in Japan. In a series of tables (pp. 271-276), the minimum hours per year and periods per week to be devoted to science and other subjects are given for the elementary schools and lower secondary schools. The minimum hours per school year for science range from 68 in the first year of the elementary school to 140 in the lower secondary school.

One of the characteristics of elementary school science in Japan is the humanistic approach and the concerted attempt to develop an appreciation of nature and respect for life. A characteristic of Japanese society, exemplified by the history of elementary school science, is its ability to absorb ideas and practices from other societies and cultures, adapt them, and then eventually make them their own. These two characteristics are highlighted in "One Hundred Years of Elementary School Science in Japan" (8) by Hokichi Nakagawa.

As early as the 1870s, following the Meiji Restoration, five separate subjects were prescribed for science in elementary schools: hygiene, natural philosophy, natural history, chemistry, and human physiology. Later in the 1890s, the stress was on more accurately observing ordinary natural things and phenomena and gaining an understanding of the relationships between natural things and phenomena and with human life. This aim of developing a feeling for living things has been continued into the course of study that is now in use in the elementary school.

The list of influences from other cultures and societies is long and the following are examples:

Chinese classics
Pestalozzian educational philosophy
Heuristic approaches from Guthrie and Armstrong in England
German "Naturkunde"
Such German educators as Hausknecht, Herbart, Junge and Beyer
American elementary science after World War II

All these influences have had an impact, but the Japanese have been able to adapt, extend, and make them their own.

Nakagawa suggests two rules and a major problem that are identified in the review of one hundred years of elementary school science in Japan. He suggests that an obvious rule is that international tension is a strong stimulus for the development of science education. More importantly, he suggests that the quality of science teachers is crucial to the progress of science education. The importance of having well qualified science teachers is emphasized. A continuing problem is how to develop the pupil's scientific creativity and scientific way of thinking. Much later in the 1980s, this problem continues to concern those who are calling for reform in Japanese education.

From a secondary school perspective, Nobuichi Hashioka, in "Science Education in Lower Secondary Schools with Special Reference to Historical Survey of the Curriculum and Its Present Status" (9), reviews the history of lower secondary schools in Japan from 1886 to 1968. The year 1886 is considered to be the start of modern education in Japan, and it was only one year later that the Ministry of Education required a laboratory be set up in every middle school equipped with experimental apparatus. Even then, it was believed that science should be taught by experiments and observation.

Many changes were wrought over time. For a period in the early 1900s, the Ministry of Education stressed "giving knowledge," as opposed to experimentation. This was revised in 1911, however, with a curriculum that attempted to relate living creatures to their environment. The effects of World War I caused Japan to focus more heavily on science education that could help industry; and in 1931, another revision created a two track system of general and applied sciences. This approach was discarded in 1943, and a different two track system, one of inanimate nature and one of biology, was set up.

Japan's educational system was revised again, after World War II, under American influence. The curriculum focused on ways for students to live better lives, and it was called "life education." A further revision in 1951 merely clarified that of 1947.

In 1958, the Ministry of Education announced a new mandatory curriculum, as "Life education" was not aiding Japan's economic growth. This new curriculum was an attempt to bring Japan to the forefront of the world's cultural, scientific, and industrial progress. Although its stated aim once again emphasized experiments and observation, in practice, insufficient hours had been provided, and a lecture style-of-teaching prevailed. Furthermore, with the large numbers of students applying for entrance to upper secondary schools, preparation for entrance exams became the focus of education, and true science teaching lost precedence.

Japan is one of the nations that has demonstrated that education does contribute and may be essential for scientific, technological, and economic development. With few natural resources other than its human resources, Japan has moved from a state of massive destruction during World War II to a complex technological society, and education has been a major factor in this development. Makoto Aso and Ikuo Amano, in their Education and Japan's Modernization (10) trace the development process of

Japanese education in terms of the expanding opportunities for education, the emancipation of individual persons, the contribution to the nation's industrialization process, and the increasing participation of individuals in political, economic, social, and cultural processes. They trace the development of the modern Japanese educational system from the Fundamental Code of Education promulgated in 1872. They point to the more recent essential contributions of education to the "national income-doubling program." They note the concept "investment in education," and particularly the investment in the training of scientists and technicians as strategic manpower influencing the speed of economic growth. The inauguration of the five-year program, which combined three years of upper secondary education and two years of higher education to produce middle level technicians, was noted. Natural science and engineering departments in national universities have had substantial increases in enrollments, as well as an increase in the number of such departments. In the 1970s it was agreed that the educational system needed re-examination, and the following points were agreed upon:

1. As the percentage of an age cohort entering senior high school passed the 90% mark, the educational system should be changed to reflect the broader population now being served by the schools.
2. For further modernization in the society, the school system had to become less standardized and rigid to adapt to a society of rapid change and diverse values.
3. The upper secondary school system had to be reformed in order to provide terminal education for future citizens as well as educating students for university examinations.

Japanese education has undergone remarkable development over the last 100 years. It has been a vital factor in making rapid modernization in the society possible.

In Education and Equality in Japan (11), William Cummings reveals some interesting information about the meritocratic approach to education that is used in Japan. In an effort to give all students an equal chance at education, to instill in the populace a strong interest in education, and to have the "most able products of the schools...selected for the most important positions in society," Japan developed an examination system of education that is fundamentally egalitarian. Ideally, any one, no matter what their wealth or status, can get into a preferred university if their exam scores are high enough. Realistically, however, wealth (at least moderate wealth) does make a difference. In order to do well on the entrance exams, most students must attend jukus (after-school study centers) or have private tutors. Naturally, these forms of extra-education can become expensive. Families must be willing to spend considerable sums of money on their childrens' education. Monthly fees, according to Cummings (1976), run about one-quarter of the average monthly family income. The more well-to-do families spend an even greater proportion (up to 40%) of their income on jukus and tutoring. It would seem, therefore, that equality in education may not actually be as egalitarian as it appears.

What is life like in Japanese schools? Thomas P. Rohlen in Japan's

High Schools (12) describes the findings of an American ethnographer's observations during 13 months of fieldwork in five Japanese high schools. He describes his book as resembling two concentric wheels. The inner wheel is the high school, and the outer wheel is the more general sociological and cultural questions. There are interactions along the spokes between the wheels. There is a discussion of the social and historical context of the schools--the outer wheel. The inner wheel, the schools, are described in terms of space and time, organization, politics, instruction, and the adolescent pattern. Under space and time, there is a very interesting description of the physical features of the schools. Science labs, for example, may have plants and educational materials around, and, like art and music rooms, cause students to tend to gravitate toward them. A number of striking conclusions are drawn. Academic stratification rests on entrance exams and occurs at transfer points between school levels. It is suggested that Japanese schools are basically more efficient then American schools. Japanese students spend more time in schools, do not lose half of what they have learned during the long summer, and devote more time to such basic subjects as science. Rohlen estimates that the average Japanese high school graduate has the basic knowledge equivalent of that possessed by the average American college graduate. The great accomplishment of Japanese elementary and secondary education is not the creation of a brilliant elite but the generation of a high average level of capability. Should the United States adopt components of Japanese secondary education? Rohlen suggests that education is a reflection of a culture and the state of a society. It may be that the U.S. should give greater emphasis to the development of its human resources and that this goal should have highest priority. The U.S. should not emulate Japanese institutions but try to match their accomplishments. "Japanese high schools can be a mirror but not a model for Americans."

It is highly desirable that creativity be nurtured through education, and questions are raised about the nurturance of creativity in Japanese society and its schools. E. Paul Torrance in "Lessons About Giftedness and Creativity from a Nation of 115 Million Overachievers" (13) examines creativity in Japanese society and suggests ways that the United States can deal with its problem of underachievement. A long list of Japanese achievements, from leading the world in number of inventions and patents to publishing more novels each year than any other country, certainly leads us to question the notion that the Japanese may be less creative than others. Based on a collaboration with Japanese scholars and a three month study tour, Torrance suggests ways that creativity could be nurtured. He suggests that creative achievement, particularly among children and young people, should be rewarded. More emphasis, as in Japan, should be placed upon intuitive ways of knowing, and on the persistence and the "long look" that is necessary in most creative endeavors. Self-directed learning should be given more emphasis, as well as group learning and problem solving. In Japan, a great deal of study and learning activities are carried out in groups, and there is little pressure against an individual for excelling because the individual is identified with a group. A national climate in the U.S. should be established that is more favorable to the expression of giftedness and creativity and that the entire society should assume "...responsibility for stimulating to the fullest the potentials of our children."

In Japan As Number One (14), Ezra F. Vogel discusses the advances made by Japan since 1960. With an illiteracy rate of less than one percent, Japan is also a scientifically literate nation. As an example, Vogel tells us that even on commercial television, news commentators are able to use various chemical formulas when discussing scientific topics.

As with many observers, however, Vogel admits that Japan does have its weaknesses. Disagreeing with Torrance, Vogel feels that Japanese students are much more likely than American students to closely adhere to guidelines rather than to develop creativity. Also, although nearly twice as many males in their mid-twenties have completed a four-year college program in Japan (40%) as compared to the U.S. (20%), expenditures per student in the universities are "unreasonably low". Vogel points out, in addition, that graduate education is rare, and that "the level and variety of advanced research are highly limited".

Japan has been called a nation of overachievers. It is a nation that ranks first each year in the number of inventions and patents, leads in the number of novels published, has higher test scores in science and mathematics than the U.S., has a higher economic and productivity growth rate, and has leaped from peasant to modern society in a century even while suffering horrendous devastation in World War II. This is a nation that should be studied and better understood. Diane Profita Schiller and Herbert J. Walberg in "Japan: The Learning Society" (15) suggest that the key to these achievements is the steady, large educational investment in human resources. They identify seven factors: age and developmental level, quantity of instruction, quality of instruction, motivation, home learning environment, and classroom social environment. Perhaps of special importance to science education are the Japanese views of ability, motivation, and quantity and quality of instruction. Disciplined study is considered more important than innate ability. Teachers have responsibility for motivation, and persistence is viewed as a key to effective motivation. Japanese schools are in session approximately 240-250 days as contrasted to approximately 180 days in the U.S. In addition, Schiller and Walberg note that children seem to be constructively engaged in lessons 85% of the time as contrasted to as little as 25% of the time in the U.S. The quality of instruction is enhanced by periodic in-service education for teachers. The large and steady investment in education has brought great dividends, and their experience deserves study.

The National Science Foundation (NSF) report, "How the U.S. Compares with Other Countries" (16), contrasts science and math education in the U.S., Japan, West Germany, and the Soviet Union. A positive correlation is made between productivity and world trade, and the number of engineering degrees earned in each country. Between 1963 and 1977, Japan has increased in both areas while the United States has decreased. This supports the opinion, as discussed by Aso and Amano in Education and Japan's Modernization (10), that a scientifically literate population is necessary to keep a nation functioning as a major world power. Japan seems to realize this fact and stresses science education for all its people. In the U.S., however, science education has been on the decline, with fewer and fewer high school students taking science courses beyond

10th grade. The NSF feels that the public must be made aware of the importance of science education for our national well-being.

In "Japanese Education: Its Implications for Economic Competition in the 1980s," (17) Michael W. Kirst states that the U.S. has a serious shortage of workers in engineering and technology. Not only are there more technicians graduated in Japan than in the U.S., but there are also more baccalaureates granted in engineering. One possible explanation for this is that negative public attitudes about science discourage American students from taking science courses, while public support of science education in Japan has allowed that country to overtake the rest of the world in modern technological developments. Japanese achievement scores in science are "the highest in the non-Communist world," and Kirst points out the irony of this: Japan's science curriculum has taken into account material developed in the U.S. with funds from the National Science Foundation (NSF) in the 1960s and 1970s--material rarely used in this country today. Teaching methods do differ, however, and while some may think the use of rote learning is one of Japan's educational weaknesses, Kirst feels this style helps students to "discriminate tiny variations in routines" which may be an asset in learning to improve new technology. Kirst does not think the U.S. should copy the Japanese system, but he does think American educators should be more aware of the Japanese curricula.

It is generally held that effective education is essential in modern, technological societies. Has Japanese education contributed to Japan's industrial development? Will it be adequate for future development? Lawrence P. Grayson, in his three-part report, "Japan's Intellectual Challenge" (18), concentrates on the implications of education based on industrial needs.

The trend during the past 30 years has been to lean heavily on industrial education as a means of rebuilding the economy and enable Japan to compete in the international marketplace. In elementary and lower secondary schools, over 25% of class time is spent on math and science. Students are taught concepts not usually reached in U.S. schools until the upper secondary or college level. Troost states that over 94% of Japan's student population goes to upper secondary school, and every high school student, whether in an academic or vocational track, takes three years of mathematics (compared to the U.S. where only about one-third of high school graduates have had three years of math). Most Japanese high school graduates have also completed courses in three natural sciences, some aspects of these courses have been based on U.S. curricula and adapted to Japanese needs. At the end of upper secondary schooling, it has been estimated that Japanese students have had two to four years more classroom time than U.S. graduates. This may make it easier to understand how Rohlen, in his book, Japan's High Schools (12), can claim a Japanese high school education to be equivalent to a U.S. college education.

Three types of higher education are available in Japan. The technical college combines three years of upper secondary schooling with two years of college. These schools stress the applied aspects of science and technology, and provide most of the work-force for industry.

The second type of school is the junior college, which was introduced during the post-war years by American advisors. Students entering a two-year junior college are high school graduates wishing to take technical training. These colleges are held in low esteem, however, granting only a certificate (as opposed to the degree granted by technical colleges). Industry will not usually hire junior college graduates, and perhaps this helps explain why over 92% of the graduates are women. Junior colleges have become the way to educate future wives and mothers.

According to Grayson, about 33% of Japanese high school graduates attend a four-year university, and there has been much publicity about the rigid entrance examinations and the virtually guaranteed employment that comes with graduation. Interestingly, few Japanese go on to earn higher degrees. As previously noted by Vogel (14), the opportunity to become involved in advanced research is severely limited. A fairly obvious reason for this may be that industries prefer to hire Baccalaureates and train them for specific job openings as they occur. In Japan, prospective employees with graduate degrees are actually at a disadvantage. In 1982, in the field of engineering, one out of 46 recent Bachelor's degree holders and one out of 58 recent Master's degree holders were unemployed, while one out of seven Ph.D.'s was without a job. This trend will have to change if Japan is to retain her lead in technology. Until now, Japan's success has been based upon adaptation of foreign ideas, but Grayson points out that with rapid changes in state-of-the-art technology, it is becoming increasingly difficult to stay ahead by simply modifying existing technology. Unless the Japanese can learn to develop their own inventions, they may encounter problems. Since there has been little evidence of creativity in the past (according to Grayson), it seems apparent that some changes must be made. One way to change thinking patterns is to change the style of education. Individuality, originality, and research should be stressed, with less emphasis placed on rote learning. Grayson also feels that more students should be encouraged to continue their education beyond college, thus enabling them to have the background necessary to conduct original research. If critics say the U.S. should learn from the Japanese, they must also realize that the Japanese can take lessons in creativity from the U.S.

"The Japanese genius appears to be the ability to receive innovations, whatever they may be, and elaborate upon them until they become Japanese in outlook." A discussion of how this ability has been applied in Japan's elementary school science is described in a paper, "People, Society and Science Education in Japan," which was prepared for and presented at a U.S.-Italy Joint Seminar on Science Education for Elementary School Children (19). Science courses have been designed in Japan that were in harmony with research on learning in America. However, it was found advantageous to add and change because it was discovered that there was not enough attention to intelligent use of leisure and self-realization. Also, not enough attention was given to the aim of applying scientific knowledge and the spirit of inquiry to human needs. Areas such as aesthetics and affective and creative domains seem to have been neglected. Students should gain an understanding of the relationship of science and technology, and how they both contribute to the advancement of human welfare.

To correct inadequacies, a new orientation for the teaching of elementary school science has been designed:

- To develop the ability and attitude of the children to investigate nature.
- To understand natural objects and phenomena.
- To enhance appreciation and love for nature through observation and experimentation. (20)

The Japanese appear to be able to recognize, borrow, and improve upon good ideas wherever they may be found. For example, American psychologists, such as Kurt Lewin, Rensis Likert, and many others advocated the use of graphics and group discussions with workers to improve productivity. These techniques are now being used by Matsushita and other Japanese firms in their factories. Herbert J. Walberg in his "Scientific Literacy and Economic Productivity in International Perspective" (21) discusses the economic and psychological aspects of literacy, some international comparisons of science achievement, such as the IEA study of science achievement in 19 countries, science education in the U.S.S.R. and in the People's Republic of China, and focuses on Japan as a case study. Of special interest is the discussion of literacy and economic productivity. To be internationally competitive, nations must have men and women who have a high standard of literacy--especially scientific, quantitative, and technical literacy. The United States is declining in scientific literacy. The growth in productivity in Japan and West Germany exceeded ours by three percent to six percent. However, progress in productivity comes mainly from adapting scientific and technological ideas, and in this the Japanese have demonstrated considerable success. It is not enough to have outstanding scientists. There must also be educated workers who are skilled in handling materials and data, can absorb and propagate applied science, and can communicate and cooperate with one another. Increasing the effectiveness of our schools should be part of the long-term solution to problems of economic productivity.

The great strides made in recent years by Japanese technology have caused many Americans to urge a reform in our own educational system, adopting those practices which seem to have made Japan successful. John J. Cogan, in his "Should the U.S. Mimic Japanese Education? Let's Look Before We Leap," (22) counsels against rash assimilation of the Japanese system. He describes how Japanese education has changed greatly over the years, adapting itself to contemporary needs. The reason Japan has succeeded, Cogan states, is because of its ability to retain its own culture and tradition while carefully choosing foreign methods which it then molds to its specific requirements. Cogan feels that the U.S. should reform its educational system, but it should not jump blindly onto the Japanese bandwagon. While there is much to be said for the Japanese schools' focus on "the basics," for their ability to encourage long-range goals, and for their success in teaching appropriate behavior patterns, they also demonstrate a number of weaknesses. School violence, a system favoring the wealthy, and jukus are some of the issues on Cogan's list. But these, as well as other factors, are all related to one overriding weakness: the amount of pressure put on students to score well on both high school and university entrance examinations. This pressure not only burdens the students, but also puts a financial burden on the parents. (Some parents spend up to 40% of their income on their childrens' education.) Cogan warns that although the system works for the Japanese, it is not perfect, and the danger we face in trying to adopt it in its entirety is that we will incorporate the weaknesses as well as the strengths.

Reading professional journals is one way of keeping abreast of current developments in various fields. Unfortunately, few professional journals in Japan are printed in languages other than Japanese. It is for this reason that we are especially indebted to the Japan Society for Science Education for its annual English edition of Kagaku Kyoiku Kenkyu (Journal of Science Education in Japan) (23), which has been published each year since 1978.

The first English edition contains the proceedings of the Japan-United Kingdom Science Education Seminar, held in Tokyo in November 1978. Succeeding journals contain articles ranging from the history of science education in Japan ("Science Education in Japan after World War II", Volume 3) to social influences on science education ("Social Goals and Science Education in Japan" and "Social and Economic Influences in Curriculum Change in Japan", Volume 4) to a U.S./Japan seminar on chemical education (Volume 5). There are a number of articles on computer-assisted instruction, especially in Volume 8, which contains the proceedings of the Third United Kingdom/Japan Seminar on Science Education. The 1985 issue (Volume 9) takes a look at the various branches of science, with individual articles focusing on physics, chemistry, biology, and earth science.

Another means available for learning about Japanese education is the "NIER Occasional Paper," published by the National Institute for Educational Research of Japan. Two of these papers deal specifically with science-related issues. "Information Processing Studies in Japan" (24) describes how curricula at all grade levels is being modified to include utilization of microcomputers both for CAI (computer assisted instruction) and for computer education (for example, how to use computers). However, the "Use of Computers in Education in Japan" (25) admits that while the nation is nearly run by computers, the use of computers in education falls far short of what might be expected. While many upper secondary schools have microcomputers (approximately 50% of public schools and 30% of private schools), few elementary (0.1%) or lower secondary schools (1.8%) have access to such equipment. This paper on the use of computers describes the numbers and types of computers available at different grade levels, and explains the ways these computers are used. It also emphasizes the lack of sufficient teacher training in the use of microcomputers.

"The Teaching Materials System in Japan" (26) presents an outline of the educational system. Significant to science educators is the law for the Promotion of Science Education, which was enacted in 1953:

> In view of the fact that science education is most important as the basis for the establishment of a cultural state, this law, in conformity with the spirit of the Fundamental Law of

> Education and the School Education Law, has as its objective the promotion of science education, assisting the citizens to acquire scientific knowledge, skills and attitudes and to cultivate their ingenuity and creativity with a view to enabling them to carry on their everyday life in a more rational manner and to contribute to the progress of our nation.

The law also states that if the facilities for teaching science (and mathematics) do not meet government standards, the State will pay half the cost involved in upgrading the facilities. In addition to subsidizing school science classrooms, the government also subsidizes local science centers. These centers provide up-to-date apparatus for the in-service training of science teachers.

Bentley Glass visited and discussed the phenomenon of science education centers in "The Japanese Science Education Centers." (27) Written in 1966, just six years after the inception of these centers, Glass described the physical plants and the type of staffing at each of the six centers he visited. These centers were formed by local teachers, administrators, and boards of education, and are partially funded by the Ministry of Education. The labs purposely resemble ordinary high school science labs, but more elaborate equipment and collections are also on hand. In this way, teachers are able to practice classroom skills and are also able to gain knowledge of special equipment (for example, electron microscopes, x-ray machines, and telescopes) to which they would not normally have access. While the primary purpose of the centers is to update science teachers by allowing these teachers to bring groups of students to demonstrations, the centers also serve to introduce students to more sophisticated equipment than can be found in a typical high school.

An important aspect' we should bear in mind is that these science centers are permanent facilities. Teachers can attend sessions during the year. The U.S. has museums, zoos, botanical gardens, and nature centers, but has no strictly comparable institution to the Japanese science education centers. In America, there are many summer programs, usually on specific topics, but there is often no follow-up and sometimes no direct correlation to high school curricula. Interestingly, all the centers visited by Glass utilized American science programs (BSCS, PSSC, CHEM, CBA, and ESCP), the same programs that had been adapted for use in the Japanese secondary schools. Glass considered the science centers of Japan to be one of the world's most significant contemporary educational experiments.

Most science educators believe that "hands-on" science experiences are of critical importance. Many teachers in Japanese elementary and secondary schools have expressed the belief that "hands-on" experiences are very important and observations in Japanese schools indicate that many Japanese teachers actually engage students in such activities. The actual implementation of "hands-on" activities may help explain some of the differences in science achievement between Japanese and American students. In one of the first and few empirical studies of practical (laboratory) achievement in science, Shigeo Kojima in his article "IEA

Science Study in Japan with Special Reference to the Practical Test," (28) describes the administration of practical tests and the results. Stratified two-stage random samples of 10-year-olds and 14-year-olds were drawn. The students responded to such practical items as measuring the area of a leaf-like figure by counting squares, finding differences between photographs of two fruit flies, observing chemical changes, measuring length, and measuring electric currents after using a diagram to construct an electrical circuit. Interestingly, it was found that students are more likely to recognize a precipitate when it is formed than to recognize that the precipitate later dissolves. Perhaps, most importantly, it was found that it is possible to conduct such testing with several thousand students. It was discovered that the practical tests measured important aspects of science achievement that are not measured by paper-and-pencil type tests. In the Second IEA Science Study, such practical tests have been given in several other countries, but the results have not yet been reported.

Many researchers agree that, in Japan, ability is viewed as less important than persistence. Students believe that anyone can do well as long as they study hard enough, and Japanese families are seriously involved in making sure their children do well. Kay Michael Troost, in "What Accounts for Japan's Success in Science Education?" (29) brings out another facet of family participation. He has found that a student's perception of his or her family's interest in science is a strong predictor of the student's own interest. Also, the results of the First International Association for the Evaluation of Educational Achievement (IEA) Science Study (FISS) showed that the association between the mean scores on liking science and achievement in science was highest in Japan (compared to 18 other countries). In achievement, in the IEA science study, the Japanese placed number one for both the 10-year-old and 14-year-old groups, among the 19 countries taking part. (The U.S. ranked number four and number seven, respectively). In the "opportunity to learn" section of this study, not only did the Japanese high school students have the greatest topical coverage, but they also had more advanced coverage. Math and science courses are commonly integrated, with advanced science courses requiring a knowledge of calculus. Troost reports that about 20% of Japan's students took these advanced courses. In the U.S., only about 2% of high school students took calculus.

Science education begins at an early age in Japan. According to Troost, about one-third of the time in elementary school is spent in "hands-on" science activities. This helps students to grasp ideas and concepts intuitively. It is not until students have a strong foundation that they are weaned away from lab-oriented science and forced to concentrate on lecture-oriented science and the studying for examinations. (At the lower secondary-level, lab time decreases to about one-eighth of total class time).

Nikkyoso, the Japanese teachers' union, stresses education of the person as a whole. The creative use of science and the impact of science on society are only two of the alternative viewpoints that may be discussed in the curriculum, where the emphasis is placed on developing positive feelings for science. This is carried over into the home. Kagaku No Zasshi (Science Magazine) reaches approximately one-half the homes of students at each elementary grade level, and both commercial and educational television present more scientifically advanced programs than do their U.S. counterparts.

Troost also feels that the professionalism of Japan's science teachers is an important factor in science achievement. (This professionalism is based upon membership in professional associations and attendance at professional meetings). Science teacher training is oriented primarily toward science, not toward education. Perhaps surprisingly, most of the country's science teachers are graduates of the National Universities, which are the most selective of the college level institutions. It may be a reason that teachers in Japan have a much higher status than do teachers in the U.S., and that relative to other occupations, they also have higher salaries.

REFERENCES

1. Torsten Husen, "Are Standards in U.S. Schools Really Lagging Behind Those In Other Countries?" Phi Delta Kappan 64 (March 1983), pp. 455-461.

2. Nobuo K. Shimahara, "Japanese Education and Its Implications for U.S. Education," Phi Delta Kappan 66 (Fall 1985), pp. 418-421.

3. Japan, Ministry of Education, Science and Culture, Course of Study for Elementary Schools in Japan, No. 155 (1983).

4. Japan, Ministry of Education, Science and Culture, Course of Study for Lower Secondary Schools in Japan, No. 156 (1983).

5. Japan, Ministry of Education, Science and Culture, Course of Study for Upper Secondary Schools in Japan, No. 163 (1983).

6. Japan, Ministry of Education, Science and Culture, Mombusho, 1981.

7. Japan, Ministry of Education, Science and Culture, Research and Statistics Division, Japan's Modern Educational System-A History of the First Hundred Years, 1980.

8. Hokichi Nakagawa, "One Hundred Years of Elementary School Science in Japan," Education in Japan 3 (1968), pp. 45-59.

9. Nobuichi Hashioka, "Science Education in Lower Secondary Schools With Special Reference to Historical Survey of the Curriculum and Its Present Status," Education in Japan 4 (1969), pp. 65-76.

10. Makoto Aso and Ikuo Amano, Education and Japan's Modernization, Tokyo: The Japan Times, 1983.

11. William K. Cummings, Education and Equality in Japan (Princeton, N.J.: Princeton University Press, 1980).

12. Thomas P. Rohlen, Japan's High Schools (Berkeley, California: University of California Press, 1983).

13. E. Paul Torrance, "Lessons About Giftedness and Creativity from a Nation of 115 Million Overachievers," Gifted Child Quarterly 24 (Winter 1980), pp. 10-14.

14. Ezra F. Vogel, Japan As Number One (Cambridge, Mass.: Harvard University Press, 1978).

15. Diane Profita Schiller and Herbert J. Walberg, "Japan: The Learning Society," Educational Leadership 39 (March 1982), pp. 411-412.

16. National Science Foundation, "How the U.S. Compares With Other Countries," Educational Leadership 38 (February 1981), pp. 368-370.

17. Michael W. Kirst, "Japanese Education: Its Implications for Economic Competition in the 1980s," Phi Delta Kappan 62 (June 1981), pp. 707-708.

18. Lawrence P. Grayson, "Japan's Intellectual Challenge," in 3 parts, Engineering Education (December 1983):138-146; (January 1984):210-220; (February 1984), pp. 296-305.

19. Shigekazu Takemura, "People, Society and Science Education in Japan," in Proceedings of U.S.-Italy Joint Seminar in Science Education for Elementary School Children, eds. Doris E. Hadary and Matilda Vincentini (Washington, D.C.: The American University, 1983), p. 153.

20. Ibid., p. 155.

21. Herbert J. Walberg, "Scientific Literacy and Economic Productivity in International Perspective," Daedalus 112 (1983), pp. 1-28.

22. John J. Cogan, "Should the U.S. Mimic Japanese Education? Let's Look Before We Leap," Phi Delta Kappan (March 1983), pp. 463-368.

23. Kagaku Kyoiku Kenkyu (Journal of Science Education in Japan), vols. 2-9 (December 1979):141-194; (December 1980), pp. 117-198; (December 1981), pp. 121-206; (June 1982), pp. 47-88; (June 1983), pp. 39-84; (June 1984), pp. 39-164; (June 1985), pp. 39-92.

24. Information Processing Studies in Japan, NIER Occasional Paper 01/85 (Tokyo: National Institute for Educational Research of Japan, 1985).

25. Use of Computer in Education in Japan, NIER Occasional Paper 03/84 (Tokyo: National Institute for Educational Research of Japan, 1984).

26. The Teaching Materials System in Japan, NIER Occasional Paper 02/84 (Tokyo: National Institute for Educational Research of Japan, 1984).

27. Bentley Glass, "The Japanese Science Centers," Science 154 (14 October 1966), pp. 221-228.

28. Shigeo Kojima, "IEA Science Study in Japan with Special Reference to the Practical Test," Cooperative Education Review 18 (June 1974), pp. 262-267.

29. Kay Michael Troost, "What Accounts for Japan's Success in Science Education?" Educational Leadership 41 (December 1983/January 1984), pp. 26-29.

CHAPTER III
SCIENCE CURRICULA

Japanese children, beginning at about the age of six, enter elementary school for a period of about six years (see Figure 1). (1) This is followed by three years of lower secondary school and three years of upper secondary school. This is the familiar 6-3-3 school system. An increasing number of children attend kindergarten or some kind of pre-school. After the upper secondary school, many students will attend a university, junior college, or some other form of higher education.

Education is compulsory through the ninth grade, and it is reported that 99% of the eligible students are enrolled. However in 1983, the upper secondary education, which is not compulsory, enrolled about 93% of 15- to 17-year-old students. (2) Thus, almost all Japanese children and young people attend elementary and secondary school. A major accomplishment of this well-nigh universal education has been the emancipation of the individual, the development of the Nation's industrialization processes, and the modernization of attitudes toward the environment and participation in various societal processes. (3)

Science is one of the major subjects in both the elementary and secondary schools. Figure 2 shows the amount of time devoted to science in both Japan and the U.S. (4) While the amount of time in the elementary school is about the same, the Japanese probably devote more time to science in the secondary school. (Unfortunately, there is little up-to-date information on how much time is devoted to science in U.S. schools.)

What are the similarities and differences in the structure of science education programs in Japan and the United States? (5) The overall elementary and secondary science program in Japan is shown in Figure 3. Science is a compulsory subject for all students in the elementary and lower secondary schools, which would be grades 1 through 9. The pattern is quite similar to that in many school systems in the U.S. In Japan, Science I for 4 credit hours in the 10th grade is also compulsory but almost no students take Science II. In grades 11 and 12 in the Upper Secondary School Science, the following science subjects are electives: physics, chemistry, biology, earth science, and integrated science. Since these science courses are electives, they may or may not be chosen by students. Figure 4 indicates the percentage of students at a grade level who enroll in each of these science subjects. (6)

The percentage enrollments are estimates based upon two case studies. The 11th grade estimates are based upon enrollments at the Hiroshima attached Upper Secondary School in 1983 and the 12th grade estimates are based upon the sales of Keirinkan Textbooks in 1983. While these percentages are estimates, they would seem to indicate that secondary school physics and chemistry are more widely studied in Japan than in the United States. Probably, biology and earth science are more widely studied in the United States than in Japan. Overall, it appears that the Japanese take more science in the Upper Secondary School.

FIGURE 1

The Japanese School System

1980

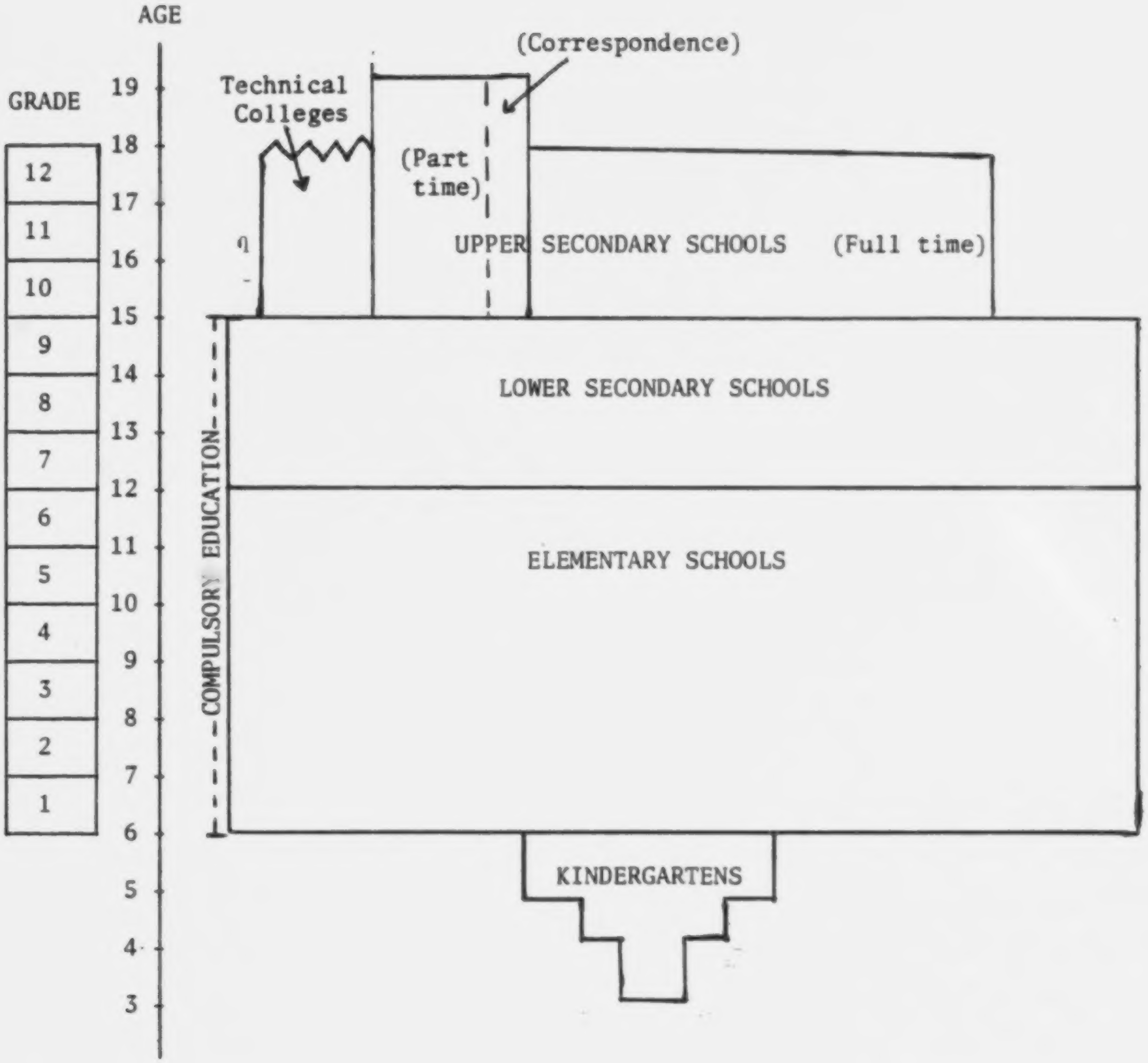

AGE
GRADE
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
12
11
10
9
8
7
6
5
4
3
2
1
Technical Colleges
(Correspondence)
(Part time)
UPPER SECONDARY SCHOOLS
(Full time)
LOWER SECONDARY SCHOOLS
ELEMENTARY SCHOOLS
COMPULSORY EDUCATION
KINDERGARTENS

FIGURE 2

Time Devoted to Science, Japan-U.S.

Country	(Grade Level)	Minutes Per Day	Hours Per Year
Japan	1-2	18	68
	3-6	30	105
	7-8	30	103
	9-10	40	140
	11-12	NA	NA
United States	1-3	19	57
	4-6	35	105
	7-9	36 (est.)	108 (est.)
	10	36 (est.)	108 (est.)
	11	NA	NA
	12	NA	NA

FIGURE 3

SCIENCE PROGRAM

JAPAN

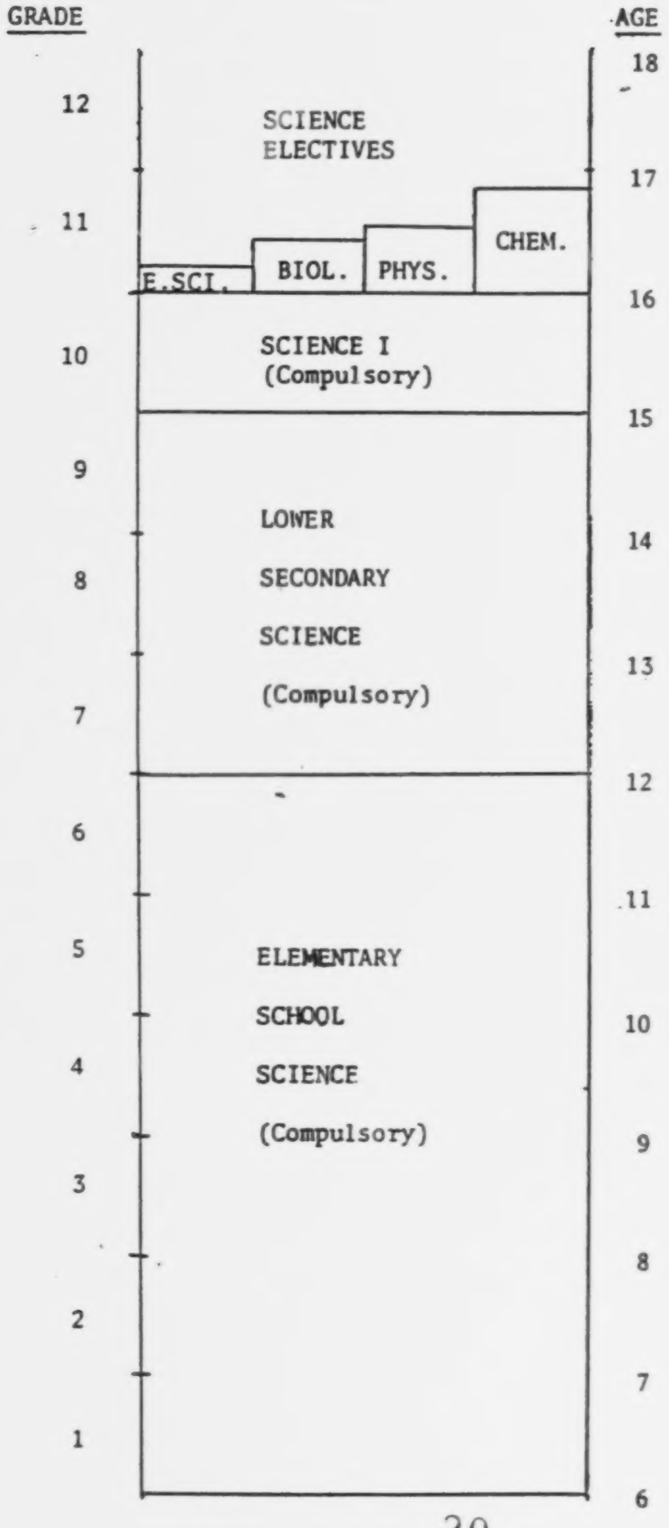

GRADE
AGE
12
11
10
9
8
7
6
5
4
3
2
1
18
17
16
15
14
13
12
11
10
9
8
7
6
SCIENCE ELECTIVES
E.SCI.
BIOL.
PHYS.
CHEM.
SCIENCE I (Compulsory)
LOWER SECONDARY SCIENCE (Compulsory)
ELEMENTARY SCHOOL SCIENCE (Compulsory)

FIGURE 4

Percentage of Students in Japan Enrolled in Science Courses in Upper Secondary Schools

Subject	Percentage 11th Grade	Percentage 12th Grade
Physics	26	23
Chemistry	42	42
Biology	21	29
Earth Science	11	6

Because of the great variety among American schools, it is more difficult to describe the organization of science instruction in American schools. However, Figure 5 shows two generalized patterns of American science programs. (7) The general patterns of science offerings in the elementary school and lower secondary school in the two nations appear to be quite similar.

Obviously, these data are imprecise and subject to error. For example, the Japanese school year is given as about 240 days and the U.S. as about 180 days. Probably, in neither country is science or any other subject taught every day that school is held. But, even though imprecise, the data give some indication of the comparative amount of time devoted to science.

The data from Japan are more readily available. (8) It is a centralized school system. The data have been published by the Ministry of Education.

The American data are often old, incomplete, or non-existent. The data for grades 1-6 are from a survey conducted in 1977. (9) Since a 1980 survey (10) indicated that almost all American upper secondary school students study at least one science, we have assumed that almost all students have some science through grade 10, and we have made our estimates on that basis. This same survey indicated that more than 50% of American students take two or more years of science and more than 20% take three or more years.

These analyses indicate that the big differences in the amount of time devoted to science instruction are in the upper secondary school. While the data may be imprecise and sometimes non-existent, the central finding is probably beyond much dispute: at the upper secondary school level, Japanese students devote more time to the study of science than do most of their American counterparts.

How do the elementary science programs compare? (11) The place of science in the Japanese elementary school is shown in Figure 6. (12) The overall objectives for science in the Japanese elementary school are, "To develop the ability in and attitude toward making inquiries about nature through observations and experiments as well as to enhance their understanding of natural things and phenomena, thereby nurturing a rich sensitivity to and love for nature." (13) For the science at each grade level there are more specific objectives. Most of these objectives can be categorized as nature study with attention given to the plants and animals in the child's environment. Starting in the third grade, there is gradual introduction of simple physical science, such as the study of air, sunlight, magnets, solutions, electric current, water, and astronomical phenomena.

In both countries, elementary school science is generally taught in self-contained classrooms by the general classroom teachers. This classroom teacher teaches most of the subjects that children study in the elementary school. While elementary science educators in both countries emphasize the importance of "hands-on" experiences in which children

FIGURE 5

Patterns of U.S. Science Education

Age	I	II	Grade	
17	Physics I	Advanced Placement or Honors: Biology, Chemistry, Physics	12	- SECONDARY LEVEL -
16	Chemistry I	Physics I	11	
15	Biology I	Chemistry I	10	
14	Physical Science	Earth Science or Biology	9	
13	Earth and Space	General or Integrated Science	8	
12	Life Science		7	
11	Elementary School Science		6	- ELEMENTARY LEVEL -
10			5	
9			4	
8			3	
7			2	
6			1	
5			K	

Optional Courses: Astronomy, Ecology, Environmental Science, Marine Biology, Oceanography, Genetics, Zoology, Physiology, Laboratory Techniques....

FIGURE 6

Number of Teaching Hours Per Year of
Science and Other Subjects
in the Elementary Schools

Classification		1st year	2nd year	3rd year	4th year	5th year	6th year
Teaching Hours of Subjects	Japanese Language	272	280	280	280	210	210
	Social Studies	68	70	105	105	105	105
	Arithmetic	136	175	175	175	175	175
	Science	68	70	105	105	105	105
	Music	68	70	70	70	70	70
	Drawing and Handicrafts	68	70	70	70	70	70
	Homemaking	-	-	-	-	70	70
	Physical Education	102	105	105	105	105	105
Moral Education		34	35	35	35	35	35
Special Activities		34	35	35	70	70	70
Total		850	910	980	1,015	1,015	1,015

Note: One teaching hour in this table represents 45 minutes.

actually handle science materials and manipulate science equipment, one of the authors of this Study has made extensive observations of elementary science classes in both countries. He believes that children in Japan actually have more "hands-on" science experiences. We should have further information on this point from the Second IEA Science Study (SISS).

The Japanese elementary schools operate about 240 days a year, and the usual length of the school year in the United States is about 180 days. Obviously, this longer school year in Japan can make possible more science experiences.

Japanese students have assignments that are supposed to be completed during the summer holiday. Some of these assignments are in science. In the fall, the children come back to the same teacher and report to this teacher on the studies carried out during the summer. Some observers of Japanese education have expressed the belief that these summer assignments reduce the amount that is forgotten over the summer break.

The following are examples of elementary science content taught in the Japanese elementary schools:

First Grade.

1. Recognize conspicuous features of living things in their surroundings. Search for and care for these living things and experience the pleasure of intimacy with them.
2. Familiarize themselves with surrounding natural things and phenomena through observations and experiments. Experience the pleasure of contact with them.

Second Grade.

1. Notice the ways of living and growth of living things. Experience the pleasure of intimacy with living things while searching for them and raising living things.
2. Observe how living things and phenomena change and experience the pleasure of association with nature.

Third Grade.

1. Investigate the growth and activity of living things. Gain an understanding of the relationship between growth and activities of living things and climate and the seasons. Foster an attitude that looks to loving and protecting living things found in the children's surroundings.
2. Examine phenomena associated with air, sunlight, magnets, etc., and gain an understanding of the properties and functions of these phenomena. Develop an interest in finding out the rules that govern these phenomena.

3. Examine the weather and changes in the temperature of soil, water, and air. Develop an interest in these natural phenomena in the pupil's surroundings.

Fourth Grade.

1. Gain an understanding of stages of growth and that life is a continuous process. Gain an understanding of the relationships between growth, nutrition, and sunlight. Foster the attitude of loving and protecting living things while observing the process of growth by raising living things.

2. Develop an interest in finding out the rules governing dissolution of solids, weight of objects, changes of state due to heat, and phenomena caused by electric current.

3. Understand the functions of running water and observe the flow of running water in a river. Gain an understanding of the shape and movement of the sun and the moon and observe their movement.

Fifth Grade.

1. Gain an understanding that living things grow under the influence of their environment. Develop an attitude of life while examining the process of the growth and body structure of living things.

2. Develop an understanding of the properties of substances and the regularity in changes. Examine how a substance dissolves and burns and how light moves and how sound is transmitted.

3. Observe the movement of the stars and understand the regularity of the movement. Foster an attitude of observing astronomical phenomena in terms of the lapse of time and the expanse of space.

Sixth Grade.

1. To understand that the growth and reproduction of plants and the human body are influenced by structure and by other living things. Develop an interest in the interrelationships between living things and their environment. Foster an attitude of respect for life.

2. To examine the mysteries of water solutions and how substances are warmed or burned. Study the functions and operation of levers, electromagnets, etc. Gain an understanding of the properties of substances and regularity in their changes. Foster attitudes that will lead pupils to investigate actively the unknown by applying knowledge to natural phenomena.

3. To have pupils examine the state of strata, the movement of the sun, and the change of temperature on the

> surface of the ground. To gain an understanding of the function of water and sunlight. To observe natural phenomena in terms of the lapse of time and the expanse of space. (14)

While there are many similarities between this Japanese outline of science content for the elementary school and outlines of content for U.S. elementary science programs, there is at least one striking difference. There appears to be much more emphasis in the Japanese program on the development of favorable attitudes toward other living things and the environment. There is also the aim to learn how to enjoy other living things and to develop a reverence for life.

How do the lower secondary school science programs compare? (15) This refers to grades seven, eight, and nine. In Japan, these are called "Lower Secondary School" and in the U.S., these grades are usually referred to as "Junior High School" or as "Middle School." In the U.S., the ninth grade is sometimes the first grade in the four-year senior high school. The subjects offered in the Japanese lower secondary school are given in Figure 7.

The overall objectives for lower secondary school science are, "To develop students' ability in and positive attitudes towards making inquiries about nature through observations and experiments, as well as to enhance the understanding of matters and phenomena in nature. Thus, to have students realize the relationship between nature and human beings." (16) In the lower secondary school, there is emphasis on observation, experimentation, and problem-solving as approaches to learning. Students have science experiences dealing with matter and energy, elements and compounds, light and heat, space and time, and electric currents. An attempt is made to develop an appreciation and respect for life and of the influence of the natural environment of humans.

In these grades in both countries, most of the science is taught by specialist science teachers. Obviously, these science teachers usually have had considerably more science training than the general classroom teacher who has responsibility for science instruction in the elementary school.

Again, in these grades, Japanese students have about 240 days of schooling each year as compared to about 180 days in the U.S. Also, these students have assignments over the summer months that are checked by the teachers when school reopens in the fall.

The following are examples of science content taught in the Lower Secondary School in Japan:

First Field. 1. To find problems among matter and phenomena related to substances and energy. Also to learn the process of inquiring into nature to discover regularities in nature and how to interpret natural phenomena.

FIGURE 7

Number of Teaching Hours Per Year of Science and Other Subjects in the Lower Secondary Schools

Classification	1st year	2nd year	3rd year
Japanese Language	175	140	140
Social Studies	140	140	105
Mathematics	105	140	140
Science	105	105	140
Music	70	70	35
Arts	70	70	35
Health and Physical Education	105	105	105
Industrial Arts and Homemaking	70	70	105
Moral Education	35	35	35
Special Activities	70	70	70
Elective Subjects, etc.	105	105	140
Total	1,050	1,050	1,050

Note: The time unit of one teaching hour in this table is 50 minutes.

2. To understand, through observations and experiments, that substances are classified into elements and compounds and further that substances consist of such particles as atoms, molecules, and ions. This should develop scientific ways of viewing and thinking about substances.

3. To gain an understanding, through observations and experiments, the features and functions of force, electric current, motions of bodies, and the work caused by light, heat, and electric current. To develop scientific ways of viewing and thinking about natural phenomena in connection with energy.

4. To gain an understanding of the function of familiar substances and energy, and to develop a positive attitude towards effective utilization of substances and energy relevant to human life.

Second Field. 1. To help students find problems among living things and their natural surroundings. To learn the processes of inquiring into nature and how to discover regularities in nature and how to interpret natural phenomena.

2. To help students realize, through observations and experiments, the diversity and unity found in living things and their surroundings. To analyze causes and mechanisms of generation of matter and phenomena, and to develop comprehensive ways of viewing and thinking about the natural world.

3. To have students, through observations and experiments, recognize the dynamism of matter and phenomena in the natural world. To consider the past on the basis of present facts and to develop a way of viewing the past in relation to the length of time and a vast expanse of space.

4. To help students consider the relationships and the harmony between matter and phenomena in the natural world. To realize the influence of the natural environment on the existence of human beings, to heighten the students interest in the preservation of biological phenomena, and to develop a positive attitude towards the appreciation of life. (17)

Again, there is a striking difference between the Japanese lower secondary school science and the science in the American junior or middle school: there appears to be a much greater emphasis on positive attitudes toward other living things and the natural environment. While this is certainly an important dimension of American science education programs as well, it is usually not as specifically emphasized.

How do the upper secondary school science programs compare? (18) In the upper secondary school, the overall objectives for science are, "To develop students' ability and positive attitude to inquire into nature through observations and experiments, to enhance their understanding of fundamental concepts of matters (sic) and phenomena in nature, and to develop students' scientific view of nature." (19)

The science subjects offered in the upper secondary school, as well as the other subjects, are given in Figure 8. There are such standard courses as physics, chemistry, biology, and earth science, as well as integrated science courses. A perusal of the course outlines indicates that they are eclectic and general in nature. The courses appear to cover the well-known, traditional topics associated with these sciences. There seems to be no indication that Japanese science educators have chosen some particular approach to a science subject, such as biology or chemistry. In the U.S., by contrast, there are biology courses that emphasize an ecological approach and physics courses that concentrate on a historical and philosophical approach. It could be argued that in a nation where you have a centralized school system, with courses of study that are used by all, a general and traditional approach has to be taken. In a large nation with a heterogeneous population, where many curriculum decisions are made at the local and state levels, it may be less risky to try out new and different approaches.

The first two courses in the upper secondary schools are integrated science courses called Science I and Science II. The content outline for Science I is:

1) Force and energy.
   Force and motion, motion of a falling body, work and heat, transformation and conservation of energy

2) Constitution of substances and their changes
   Constituent units of a substance, constituent elements of an (sic) substance, quantity, chemical changes and quantitative relationships between substances involved

3) Evolution
   Cells and cell division, reproduction and development, heredity and variation, evolution of living things

4) Balance of the natural world.
   Motion of the earth, configuration of the earth, earth's heat budget, ecosystems and circulation of substances

5) Man and nature.
   Resources, utilization of solar energy and atomic energy, preservation of the natural environment." (20)

Considerable attention is given to points to be considered in teaching.

The content outline for Science II is:

1) Observations of and experiments on specific matters and phenomena.

FIGURE 8
Science and Other Subjects in the Upper Secondary Schools.

Subject Areas	Subjects	Standard Number of Credits Required
Japanese Language	Japanese Language I	4
	Japanese Language II	4
	Expression in Japanese Language	2
	Modern Japanese	3
	Classics	4
Social Studies	Contemporary Society	4
	Japanese History	4
	World History	4
	Geography	4
	Ethics	2
	Politics and Economics	2
Mathematics	Mathematics I	4
	Mathematics II	3
	Algebra and Geometry	3
	Basic Analytical Geometry	3
	Differentiation and Integration	3
	Probability and Statistics	3
Science	Science I	4
	Science II	2
	Physics	4
	Chemistry	4
	Biology	4
	Earth Sciences	4
Health and Physical Education	Physical Education	7～9
	Health	2
Arts	Music I	2
	Music II	2
	Music III	2
	Fine Arts I	2
	Fine Arts II	2
	Fine Arts III	2
	Industrial Arts I	2
	Industrial Arts II	2
	Industrial Arts III	2
	Calligraphy I	2
	Calligraphy II	2
	Calligraphy III	2
Foreign Language	English I	4
	English II	5
	English II-A	3
	English II-B	3
	English II-C	3
Home Economics	General Home Economics	4

Note: One credit consists of 35 unit hours in the course of one school year, one unit hour being 50 minutes of teaching.

2) Surveys of the natural environment.

3) Studies on historical cases in science.

Points for special consideration in teaching:

1) One or more appropriate study themes should be selected from the Contents 1) through 3) above, and they should be included in the yearly teaching programme.

2) Selection of the study themes should be made taking into account relationships with "Science I" and referring to the following points:

   a. As for the Contents 1), scientific experiments which are the application of the content studied in "Science I" and those related to our daily life should be conducted as occasions demand.

   b. As for the Contents 2), field work concerning biology and earth science and studies on various problems relating to the natural environment should be made.

   c. As for the Contents 3), historical cases, such as the process of establishing principles and laws in respect of the important discoveries in the history of science, should be dealt with." (21)

As can be seen, the content outline for Science II is very short and lacking in detail. Apparently, it is seen as an extension of Science I with an emphasis on scientific experimentation, field work, and historical cases. The success of Science II obviously depends upon the specific experiments, field work, and historical cases that are developed. All students are required to take Science I in the 10th grade but they do not have to take Science II. Almost no students take Science II.

After the integrated science course is completed, that is, Science I, students begin to study the traditional science disciplines. The content outline for physics is:

1) Force and motion.

   a. Various kinds of motion
   circular motion, simple harmonic motion, universal gravitation

   b. Momentum
   momentum, impulse, conservation of momentum

   c. Motion of gaseous molecules
   the laws of gas (sic), the kinetic-molecular theory of gases

2) Wave motion.

a. Properties of waves
longitudinal waves and transverse waves, propagation of waves, interference and diffraction of waves

b. Sound waves
transmission of sound waves, resonance of sympathetic vibration

c. Light waves
propagation of light, interference and diffraction of light, spectra of light

3) Electricity and magnetism.

a. Electric fields
electric fields, electric potential, electric capacity

b. Electric current
electric resistance, electric current and work

c. Electric current and magnetic fields
magnetic fields accompanying electric current, force exerted by a magnetic field on a current

d. Electromagnetic induction and alternating current
induced electromotive force, alternating current, resonant circuits, electromagnetic waves

4) Atoms.

a. Electrons and light
electric charge and mass of an electron, wave nature of electron, corpuscular nature of light

b. Atoms and atomic nucleus
structure of an atom, constitution of a nucleus, radioactivity, nuclear energy" (22)

In the teaching of physics the students should have the opportunity to form the fundamental concepts in physics and apply the scientific method as developed in Science I. To make certain that students can master the content, energy and specific heat should be dealt with simply. Problems of utilization and safety of atomic power should be touched upon.

The outline for chemistry is:

1) Chemical properties of substances.

a. Inorganic substances
simple substances, compounds, confirmation of ions

b. Organic compounds
characteristics of organic compounds, compounds consisting of carbon, hydrogen, and oxygen, compounds possessing nitrogen

c. Polymers
natural polymers, synthetic polymers

2) State of substances.

a. Pure substances
gases, liquids, solids

b. Mixtures
partial pressure of a gas, solution, colloidal solution

3) Chemical reactions.

a. Rates of reaction
slow and rapid reactions, catalysts

b. Chemical reactions and the associated heat
of reaction, thermochemical equations

c. Chemical equilibrium
reversible chemical reactions, dynamic nature of chemical equilibrium

d. Reactions between acids and bases
acids and bases, neutralization, hydrogen ion concentration

e. Oxidation-reduction reaction
oxidation and reduction, electrolysis, the ionization tendency of metals, electric cells

4) Structure of matter.

a. Structure of an atom
atomic structure models, arrangement of electrons around the nucleus, periodic table of the elements

b. Chemical bond
ionic bond, covalent bond, structure and properties of matter" (23)

It is suggested that the kinetic theory of gases, rates of reaction, and the structure of an atom should be dealt with qualitatively. Although it is difficult to make comparisons between a brief outline and modern chemistry textbooks, there seems to be more emphasis on the nature of chemistry, the structure and electrical nature of the atom, and the dynamics of chemistry in modern American chemistry textbooks.

The outline for biology is:

1) Formation of a bio-organism.
    a. Formation of cells and tissues
    cells and cell differentiation, histogenesis
    b. Development and morphogenesis
    development and differentiation of animals, growth and morphosis of plants
2) Living bodies and energy.
    a. Metabolism and energy transfer
    chemical reactions to the living bodies and enzymes, anabolism, catabolism
    b. Genes and appearance of characteristics
    structure of a gene and its duplication, genes and enzymes
3) Homeostasis and regulation.
    a. Animal behaviour
    receptors and effectors, structure and function of the nervous system, stimuli and animal behaviour
    b. Homeostasis and regulation of individuals
    maintenance of homeostasis, nervous system and hormones
4) Biotic communities.
    a. Organization of biotic communities
    animal communities, plant communities
    b. Changes in biotic communities
    changes in animal communities, succession, distribution of living things" (24)

In the points for special consideration in teaching, it is suggested that the formation of cells and tissues not be done at the molecular level and that, in general instruction should be developed in a simple manner.

Unlike some American biology courses, in the Japanese program there appears to have been no deliberate effort to focus on a particular system. While they have decided not to deal with cells and tissues at the molecular level, they give some attention to cells, tissues, organs, systems, organisms, and biotic communities. While genes are considered, there is no mention of evolution. There is no specific mention of the study of the human body and reproduction.

The outline for earth science:

1) Structure of the earth.

a. Earth as a planet
characteristics of earth, terrestrial magnetism and the earth's gravity

b. Atmosphere and oceans
movement of air, movement of sea water, interaction between air and sea water

c. Earth's internal energy
earthquakes, magma and igneous activities

2) History of the earth.

a. Strata
formation of strata, stratification and contrast between layers

b. The earth's crust
recent changes in earth's crust, changes in earth's crust in eras of the geologic time

c. Evolution of the earth
primordial earth, eras of geologic time

d. Geological features of the Japanese Islands
characteristics of the Japanese Islands, formation of the Japanese Islands

3) Structure of the universe.

a. the sun
configuration of the sun, activities of the sun

b. Permanent stars
stellar radiation, evolution of stars

c. The Galaxy and the universe
the galaxy, extra-galactic nebulas, the universe" (25)

In the teaching of the earth as a planet, it is suggested the planet Earth be compared with other principal planets. Geological maps should be used. Cosmology is touched upon. Several theories of the origins of the earth should be considered, but there is no mention of which ones. The geology of the Japanese Islands is studied. The Sun is dealt with as a star. There is consideration of stellar radiation and that stellar radiation has been the key to obtain information on the universe. Plate tectonics and space exploration are not mentioned.

While Japanese science education is undergoing considerable criticism, it is a part of an educational program that has demonstrated holding power with over 90% of Japanese young people graduating from the upper secondary level. (26) Japan has made investments in education, including science education, that have contributed to economic growth.

> ...the theory of investment in education became one of the officially accepted theoretical bases for determining the direction of education policy, and investment in the training of scientists and technicians as strategic manpower influencing the speed of economic growth came to receive priority. (27)

Important changes have taken place in Japanese science education since 1950. Even greater changes are taking place now. These changes are best understood if they are placed in the context of earlier experiences. The following table (Figure 9) by Shigekazu Takemura shows the shifts in emphasis that have taken place and indicates the directions that science education is moving in Japan.

FIGURE 9

"Historical Development of Science Education

	Science Education in 1950-65	Science Education in 1965-80	Science Education in 1980-
1.	Democracy, Individual freedom	Economic growth, Sçience-technological advancement	Social welfare, love for human beings
2.	Democratic citizenship, maximum growth	Manpower-oriented, utilitarian, competition	Society-oriented, individually oriented, cooperation, self-development
3.	Experimental curriculum, child-centered curriculum, units curriculum	Discipline-centered curriculum, scientific concepts, process skills	Interdisciplinary curriculum, integrated science based on the nature of science, society and learners
4.	Reflective thinking, social problem solving	Intellectual competency	Creation, affection will power
5.	Problem-focused studies, comprehensive studies, functional thinking, scientific thinking, interests, needs, activities	Interpretive and theoretical science, logical thinking with models, concept formation and systematic framework	Observation of objects and natural phenomena, discovery of regularity and broad fundamental-conceptual schemes, doing science and applying science
6.	Guided by pedagogist philosopher and teacher job analysis	Guided by scientists and modern learning psychology as academic derivation	Wide-ranging cooperation of science, history of science, sociology, anthropology, psychology, pedagogy, etc.
7.	Learning actvities based upon child's felt needs, learning by doing, socially responsible, democratic process	Understanding in inquiring into a discipline learning a way of knowing, specific behavioral objectives, evaluation of stated inquiry skills	Group project and pacing, curiosity and excitement, not "cool" learning but "hot" learning.
8.	Individualized to socialized, Unified structured, Environment, life aspect Project methods,	Linear discipline, Highly structured, Laboratory and classroom, Discovery methods, Teacher's dominating	Cross disciplinary Loosely structured Field, lab, and classroom doing science methods, Teacher's managing" (28)

REFERENCES

1. Japan, Adapted from the Ministry of Education, Science and Culture. Mombusho, Tokyo, Japan: The Ministry of Education, Science, and Culture, 1981, p. 12.

2. Shigekazu Takemura, Study on Position of Science Education in Japan. Hiroshima, Japan: Faculty of Education, Hiroshima University, 1984, p. 10.

3. Makoto Aso and Ikuo Amano, Education and Japan's Modernization. Tokyo, Japan: The Japan Times, 1983, p. 198, Preface.

4. Adapted from Japan, Ministry of Education, Science and Culture. Mombusho, 1981, p. 22.

5. The description of the science program for grades 1-12 is adapted from Shigekazu Takemura, Study on the Position of Science Education in Japan. Hiroshima, Japan: Faculty of Education, Hiroshima University, 1984, pp. 11-16.

6. Ibid., p. 16.

7. June K. Miller, An Analysis of Science Curricula in the United States. New York: Second IEA Science Study--U.S., 1985, p. 82.

8. The Japanese data are from Japan, Ministry of Education, Science and Culture, Mombusho. Tokyo, Japan: The Ministry of Education, Science and Culture, 1981, pp. 22 and 23.

9. The American data are from Iris R. Weiss, Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education. Washington, D.C.: U.S. Government Printing Office (Stock No. 038-000-00364-0), 1978.

10. Samuel S. Peng, William B. Fetters, and Andrew J. Kolstad, High School and Beyond--A Longitudinal Study for the 1980's. A Capsule Description of High School Students. Washington, D.C.: National Center for Education Statistics, 1981, p. 3.

11. Educational and Cultural Exchange Division, UNESCO and International Affairs Department, Science and Instructional Office Bureau, Ministry of Education, Science and Culture, Government of Japan, Course of Study for Elementary Schools in Japan. Notification No. 155. Tokyo, Japan: Ministry of Education, Science and Culture.

12. Japan, Ministry of Education, Science and Culture, Mombusho. 1981, p. 22.

13. Ibid., p. 56.

14. Ibid., pp. 56-70.

15. Japan, Ministry of Education, Science and Culture, Course of Study for Lower Secondary Schools in Japan. No. 156. Toyko, Japan: Ministry of Education, Science and Culture, 1983, pp. 44-60.

16. Ibid., p. 44.

17. Ibid., pp. 44-60.

18. Japan, Ministry of Education, Science and Culture, Course of Study for Upper Secondary Schools in Japan. No. 163. Tokyo Japan: Ministry of Education, Science and Culture, 1983, pp. 49-60.

19. Ibid., p. 49.

20. Ibid., pp. 49 and 50.

21. Ibid., p. 57.

22. Ibid., pp. 51-53.

23. Ibid., pp. 54-56.

24. Ibid., pp. 56-58.

25. Ibid., pp. 58-60.

26. Shigekazu Takemura and Norman V. Overly, "Science Curriculum in Japan,"Hiroshima, Japan: University of Hiroshima, 1986, p. 14.

27. Makoto Aso and Ikuo Amano, Education and Japan's Modernization. Tokyo, Japan: The Japan Times, Ltd., 1983, p. 82.

28. Shigekazu Takemura, "People, Society and Science Education in Japan" in Proceedings of U.S.-Italy Joint Seminar in Science Education for Elementary School Children. Doris E. Hadary and Matilda Vicentini, eds. Washington, D.C.: The American University, 1983, p. 153.

CHAPTER IV
STUDENT ACHIEVEMENT IN SCIENCE

There are at least two significant reasons to analyze and compare science education in two nations such as Japan and the United States. Curiosity. What are the key features of science education in each of the nations? What factors contribute to the comparatively high science achievement scores of Japanese students? Improvement. What can science educators in each nation learn that will help them to improve their programs of science education? While alike in some ways, science education in Japan and the United States differs in ways that make it possible to probe for the effects of the differences.

While there are a limited number of sources of information in the English language about Japanese science education, both Japan and the United States have participated in the Second International Science Study (SISS). This Study provides a base of information with which some comparisons can be made. In this Study, international core achievement tests were administered to students in both countries. In the United States, the tests were administered to students in 5th grade and 9th grade, physics students in the 12th grade, and 12th grade students who were not currently studying any science. In Japan, these populations, as well as 12th grade students studying earth science, biology, and chemistry, were tested. In addition to the achievement tests, students and teachers responded to questionnaires. The SISS data have been used extensively in the analyses and comparisons made in this study in comparative science education. Also, of course, the authors have been educated in these systems of science education, and they have taught science in their systems. Thus, the authors have been able to check many of the statements made in this monograph against their quite varied backgrounds of experience.

How do the science achievements of fifth grade students in Japan and the United States compare? In the Second International Science Study (SISS), conducted under the auspices of the International Association for the Evaluation of Educational Achievement (IEA), the same achievement test was given to 5th graders. (1) (2) There were 24 items in this test, and, if rounded to the nearest whole number, the mean number of items correct in both countries was 15. There were differences (of five percent or more) between Japanese and American students responding correctly to 15 items. On eight of these items, Japanese pupils did better. On 7 of these 15 items, pupils in the U.S. had better scores. On items on which there were the greatest differences between the scores of Japanese and American children, the Japanese children had a higher percentage of correct scores on 3. One involved interpreting a table; another involved measurement. A third item on which Japanese pupils did much better was a knowledge item asking what is required for seed production. The one item on which U.S. students did much better dealt with the difference in evaporation rate of water and gasoline.

Seven of the grade five achievement test items have been classified as assessing science process skills. On five of these items, Japanese pupils had higher means, while U.S. pupils had higher means on two items. While these data have limitations, they do support the thesis that Japanese children achieve greater command of science process skills.

How do the science achievements of ninth grade students in Japan and the United States compare? In the Second International Science Study, ninth graders in Japan and the United States were tested with an international test consisting of 30 items. (1) (2) The mean number of correct items for Japan was 20 while the mean number correct in the United States was 19. There were differences (of five percent or more) between Japanese and American students responding correctly to 22 of these 30 items. On 14 of these 22 items, Japanese students scored higher, and U.S. students scored higher on 8. The item on which there was the greatest difference favoring Japanese students (grade nine) was an item involving the interpretation of a table of temperatures. This was the same item on which fifth grade students in Japan did much better than fifth grade students in the U.S. Similar to the grade five results, American ninth grade students did much better on an item involving the interpretation of an experiment studying differing evaporation rates.

Japanese students did best (95% correct) on an item asking how batteries should be inserted into a flashlight and poorest, with 20% correct, on a question asking what particles are gained, lost, or shared during chemical changes. American students did best (92% correct) on an item asking why milk in a refrigerator does not go sour for a long time, and poorest (29% correct) on a question asking them to choose the circuit inside a box to explain the observations that have been made (a "black box" question). Ten items in the grade nine test have been classified as science process items. While students in both countries appear to have done better on these items than on others, the Japanese students did better than their American counterparts on 9 out of the 10 items. Again, it appears that Japanese schools are quite effective in teaching science process skills.

How do the science achievements of upper secondary school students in Japan and the United States compare? In both Japan and the United States, 12th grade students were tested with an international core science test. (1) (2) On the 30-item international core test the Japanese physics students had a mean of 24 items right, and the U.S. physics students had a mean of 19 items right. Further, Japanese physics students had a mean of 17 items right on the 30-item international physics test, while the U.S. physics students had a mean of 10 items right. This is a difference of seven more items in the mean of the Japanese students as compared with the mean of the U.S. students. This is a very large difference. This information tends to support those critics who suggest that all is not well with physics in U.S. high schools.

Students who were not studying any science in the 12th grade were given a 30-item test in which many of the items dealt with the science that would be very helpful for the citizen to know. The mean number of items right for the Japanese non-science students was 17, and for the American non-science students it was 15. This was not as striking a difference as with the physics scores, but still, the Japanese non-science students had a better mean score than their American counterparts.

Overall in the Second International Science Study (SISS), each sample of Japanese students tested had higher mean scores (see Figure 10). The differences in the elementary school and lower secondary school were not great, but favored the Japanese students slightly. It is in the upper secondary school that we find the greatest difference in SISS science achievement scores. Of particular interest and concern is the higher Japanese achievement scores in physics. On a test dealing with traditional physics, Japanese students had a mean that was seven items higher than that of American 12th grade physics students. This is a difference that should cause concern.

What changes have taken place in science achievement since 1970? (3) (4) Both Japan and the United States took part in the First IEA Science Study (FISS). Certain items called "bridge" items were used in both the first and second science studies. By studying responses to these bridge items in 1970 and 1983, some indications can be gleaned as to changes that may have taken place in science education during that 13-year period (see Figure 11).

In the Japanese analyses of fifth grade tests, 25 items were considered to be bridge items, while 26 items were identified as bridge items in the U.S. fifth grade instruments. In the Japanese testing, students did significantly better than in 1970 on 11 of the items. The Japanese fifth grade students in 1970 did significantly better on six items. On eight items, there were no significant differences. In 1983, Japanese fifth grade students did better on almost twice as many bridge items as their counterparts did in 1970.

On the 26 bridge items identified in the American fifth grade test, American students did significantly better in 1983 on 18 bridge items. The students in 1970 did better than those in 1983 on three items. On five items, there were no significant differences. Thus, the U.S. fifth grade students showed a somewhat greater growth on the bridge items between 1970 and 1983 than the Japanese students. In part, this may be due to the fact that American scores in 1970 were somewhat lower.

In the ninth grade instruments, Japanese investigators identified 33 bridge items between 1970 and 1983. On 16 of these bridge items, the Japanese students in 1983 did significantly better than their counterparts in 1970. On seven items, the scores of students in 1970 were significantly better than the 1983 scores. On 10 items, there were no significant differences.

The U.S. investigators identified 32 bridge items in the ninth grade instruments. On 14 of these bridge items, American ninth grade students in 1983 did significantly better than did their counterparts in 1970. On seven items, the 1970 students did better. On 11 bridge items, there were no significant differences between the scores.

Conducted in the context of many policy statements in the United States, this improvement in scores in 1983, when compared to 1970, may be

FIGURE 10

Comparisons of Science Scores of Four Populations of Japanese and American Students (Items Right)

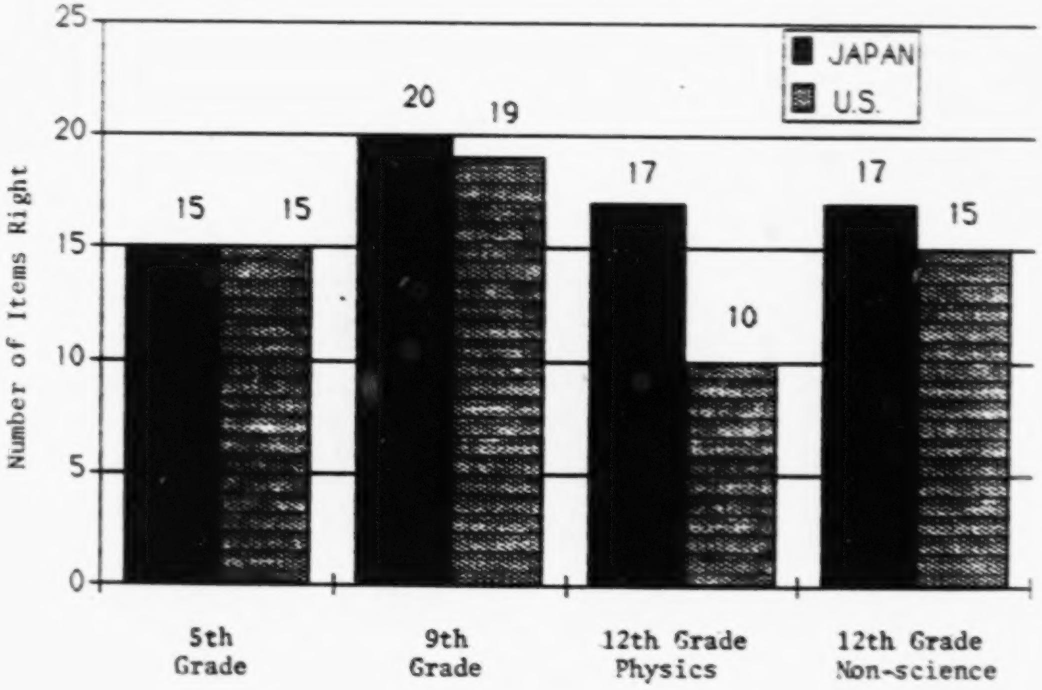


FIGURE 11

Difference in Test Performance 1970 and 1983 in Bridge Items Correct

Level	Japan	U.S.
Grade 5	1983 better than 1970 on 11 1970 better than 1983 on 6 no difference 8	1983 better than 1970 on 18 1970 better than 1983 on 3 no difference 5
Grade 9	1983 better than 1970 on 16 1970 better than 1983 on 7 no difference 10	1983 better than 1970 on 14 1970 better than 1983 on 7 no difference 11

rather surprising. But, it occurred in both Japan and the United States. It has also been found in most European countries that have taken part in both the First and Second International Science Studies. We can hope for improvement in test scores over the years. In science education, some of our hopes have been fulfilled.

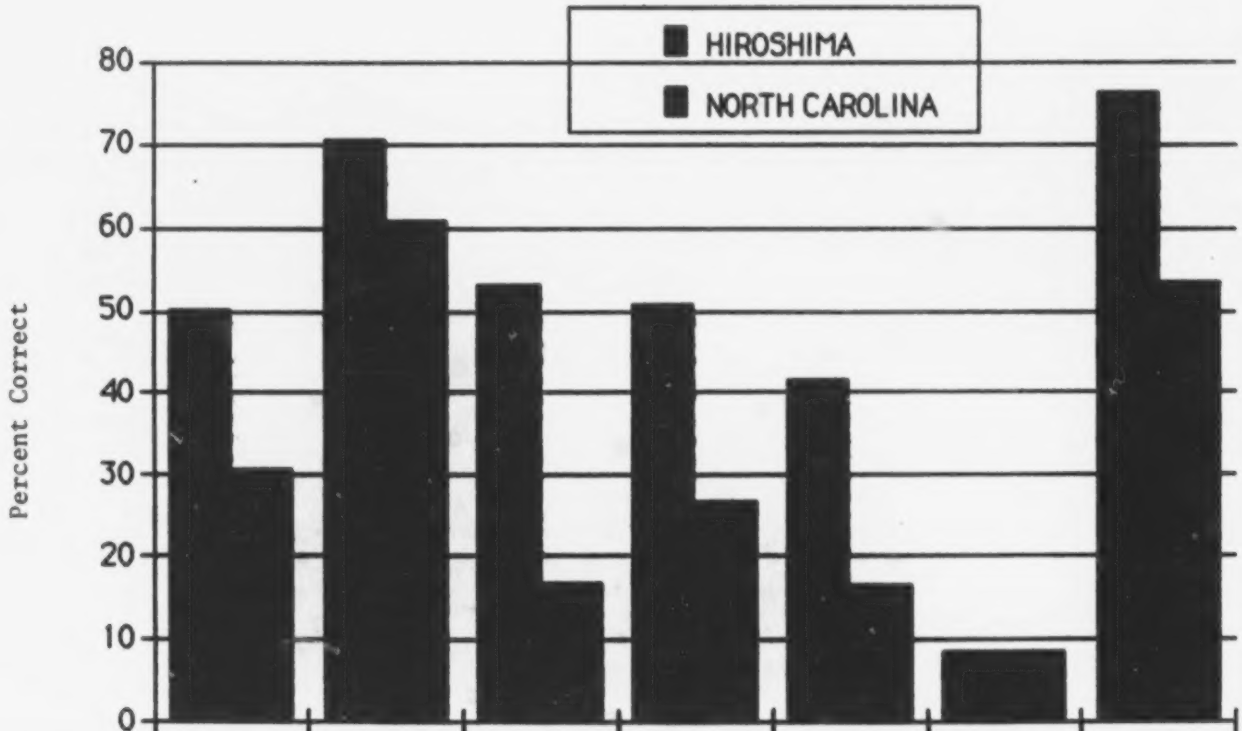
How do Japanese and U.S. students compare in reasoning skills? One of the important aims of effective science education is the development of reasoning skills. Some of the characteristics of reasoning have been identified and ways have been developed to test for these reasoning skills. One of the instruments that has been developed is the Group Assessment of Logical Thinking (GALT). (5) Another instrument is called the Integrated Process Skills Test II (TIPS). (6) These are American developed instruments, and they have been used to test seventh, eighth, and ninth grade students in Hiroshima, Japan and in the State of North Carolina. The results of these testings are of special interest in Japanese-American comparisons of science education.

The Group Assessment of Logical Thinking (GALT) measures six logical operations. The first is conservation in Piagetian terms, such as the relationship between a ball of clay and an equal mass of clay that has been flattened. The second is proportional reasoning, in which students have to determine such proportions as those between large and small glasses of water. Third is controlling variables, such as the variables that have to be controlled if the effect of changing the weight of a pendulum bob is to be studied. Fourth is probabilistic reasoning, such as determining the probability that certain sizes and shapes of objects will be pulled out next from a cloth sack. Fifth is correlational reasoning, such as determining whether there is a relationship between the size of the animals captured and the color of their tails. Sixth is combinatorial reasoning, such as determining the possible dance partners when there are three boys and three girls. In the GALT instrument, there are two items for each of these logical operations.

The Group Assessment of Logical Thinking (GALT) instrument was administered to about 3500 students in grades seven, eight, and nine in North Carolina (7) and to 4397 students in grades seven, eight, and nine in Hiroshima (8). The results for each of the logical operations, as well as the total for all of the operations are given in Figure 12 (9). Strikingly, Hiroshima students did better on all of the logical operations except one. Neither the Hiroshima nor the North Carolina students did very well on correlational thinking. The Hiroshima students did much better on proportional thinking, control of variables, probabilistic thinking, and combinatorial thinking. Actually, on some of these logical operations, more than twice as many Hiroshima students answered items correctly than their North Carolina counterparts. These are striking results, and certainly, the North Carolina researchers are right when they suggest that these logical operations and how students can master them need to be studied further.

The Integrated Process Skills Test II (TIPS) consists of 36 items that are designed to measure five process skills. The first process skill is identifying variables, such as identifying the variables that may be related to the strength of football players. The second process

FIGURE 12 - Group Assessment of Logical Thinking (Percent Correct)



	ALL	CONSER	PROP	CON VAR	PROB	CORR	COMB
Hiroshima	50.1	70.6	53.1	50.7	41.6	8.5	76.3
North Carolina	30.6	60.8	16.9	27.0	16.7	8.6	53.3

is identifying and studying hypotheses, such as identifying the hypothesis that should be tested when studying the speed of objects falling to earth. The third process is operationally defining such terms as auto efficiency. The fourth process is designing investigations, such as designing an investigation of how air pressure in a basketball affects the height of bounce. The fifth process skill is graphing and interpreting data, such as graphing and interpreting data collected in a study of the effect of temperature on the growth of bacteria.

The Integrated Process Skills Test II (TIPS) was administered to the junior high school students in Hiroshima, Japan and North Carolina, and the results are portrayed in Figure 13. (10) The Japanese students outscored their U.S. counterparts on every process skill. The differences are not as great as with the Group Assessment of Logical Thinking (GALT) scores, but there are differences favoring the Hiroshima students for each process skill. These differences occurred even though some of the items in TIPS might be construed to be culturally biased toward U.S. students. (There is an item dealing with football, and in one item, volume is stated in gallons.)

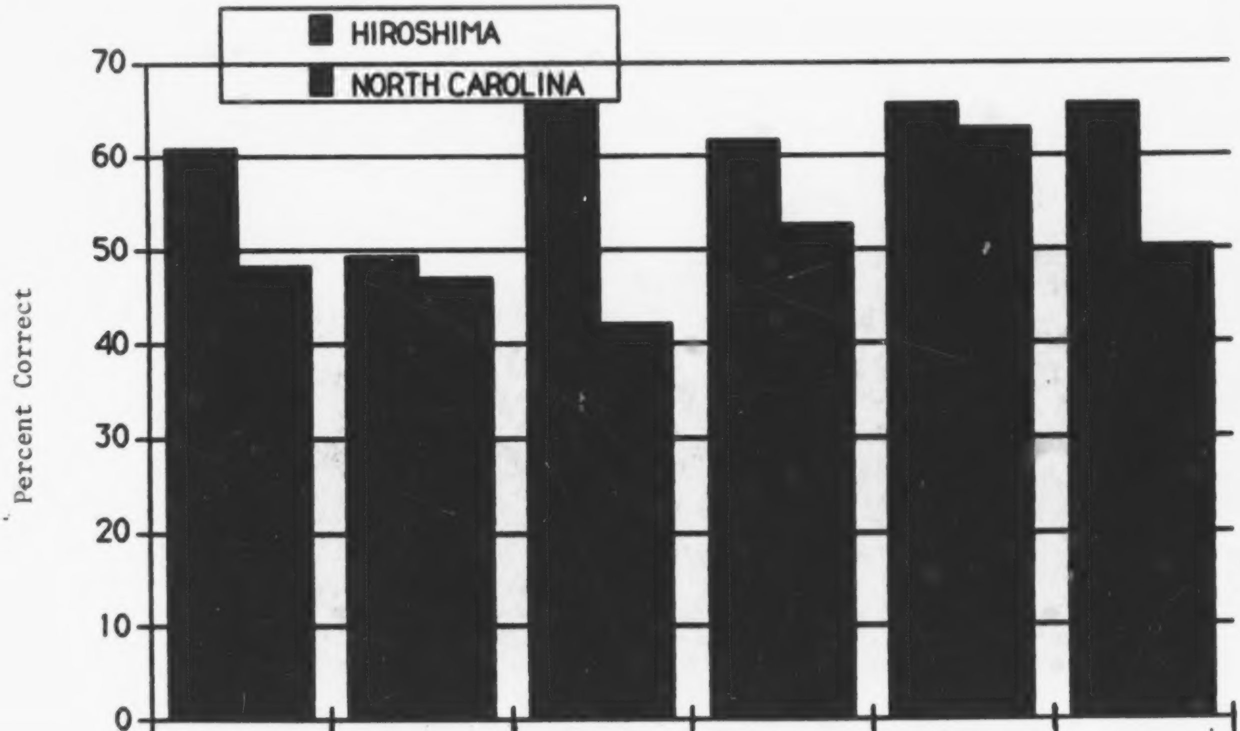
In this Hiroshima-North Carolina Study, an attempt was made to determine the Piagetian level at which the student was operating. (11) It was found that 42% of the Hiroshima ninth grade students were at formal operations, while 13% of the North Carolina ninth grade students were considered formal. Gains were made by both groups of students in the junior high school years, but there was a large difference in the scores of seventh grade students in the two countries. This large difference was carried on through grade nine. "The implication is that the low scores in grade seven for the North Carolina students is the cumulative result of the education of these students in the elementary school (grades K-6)." (12)

The differences in the TIPS II scores were similar. There was an increase in scores from grade seven to grade nine in Hiroshima and North Carolina with the greatest increase between grades eight and nine. Again, it is suggested, "The inability of the North Carolina students to handle the integrated process skills may reflect the lack of experience these students have had in their educational experiences in grades K-6." (13)

What are the differences in science achievement between males and females in Japan and the United States? In a number of investigations of science achievement, it has been found that males tend to do better in science than females. For example, males achieved higher scores than females in the First IEA Science Study (FISS), and the differences between the sexes increased as the level of education increased. This led L.C. Comber and John Keeves, the authors of the report of the First International Science Study (FISS), to comment, "For those who believe that girls are not given fair treatment, the IEA findings provide dramatic evidence of the scope of the problems." (14)

In 1983, sex differences in science achievement were found in both Japan (15) and the United States. (16) The differences in mean science achievement scores of males and females in the United States, 5.7% in

FIGURE 13 - The Integrated Process Skills Test II (TIPS) (Percent Correct)



	ALL	ST HYPO	ID VAR	OPER DEF	DESI EXPERI	GRAPH
Hiroshima	60.9	49.3	65.7	61.6	65.5	65.6
North Carolina	48.2	46.9	42.2	52.7	63.0	50.3

grade five and 6.4% in grade nine, were greater than those in Japan. In Japan, the differences favoring the males were 1% in grade five and 5% in grade nine (see Figure 14). In both countries, the sex differences increased from fifth grade to ninth grade. In the U.S., the differences were even greater with the 12th grade population studying physics (9.1%). (The gender differences for physics students in Japan were small: 1.3%) Apparently, in the United States the longer males and females continue in school, the greater the differences in science achievement. The one exception to this in the U.S. was with grade 12 students not studying science, where the male-female difference was 4.8%. The sex differences in Japan also increase with grade except for grade 12 students studying physics, where the difference was 1.3%.

Such sex differences have been found in many of the countries reporting on science achievement in the Second International Science Study (SISS). Many American science educators and others will be surprised and concerned to learn that, in general, there were greater differences in science achievement between males and females in the United States than in Japan.

What variables correlate with science achievement in Japan and the United States? In the Second IEA Science Study (SISS), carried out in Japan and the United States, students were asked to give information about themselves, about science and school, and to respond to a science learning instrument that elicited information about their science experience in school. (17) (18) Correlation coefficients have been calculated between many of these variables and science achievement on the international core test that was responded to by all students in each of the populations. Correlations are available for the fifth grade and the ninth grade. As usual, the reader should be cautioned that correlations can indicate possible relationships but do not indicate a causal effect.

The correlations for grade five are given in Figure 15 and for the ninth grade in Figure 16.

There is considerable similarity between the correlations for the two countries. In both countries, "Books in the home," "I like science," "Ease of science learning," and, at the ninth grade level, "Homework on all subjects" are variables highly correlated with scores on the international core achievement test. There are also similarities on the low or negative correlation of "Students choose topics," "Students work on topics by themselves or with teacher," and the "Discussions of careers."

There are notable differences with regard to laboratory work, tests, and homework in the ninth grade. The correlations with achievement for U.S. students are higher for "Students do experiments," "Students do lab work in small groups," and "Write up lab reports." Japanese correlations are somewhat higher for "Science Tests," and "Hours science homework." These results might indicate that there is more attention to laboratory work in the U.S., particularly in the ninth grade, and more attention to tests and homework in Japan. Do these results reflect what each country considers to be important in science education?

There are interesting differences in the use of hand calculators.

FIGURE 14

Test Performances By Sex in Percent Correct
on International Core Test

Level	Japan	U.S.
Grade 5	Male 64.8 Female 63.8 Difference 1.0	Male 61.3 Female 55.6 Difference 5.7
Grade 9	Male 69.8 Female 64.8 Difference 5.0	Male 64.7 Female 58.3 Difference 6.4
Grade 12 Physics Students	Male 81.3 Female 80.0 Difference 1.3	Male 67.8 Female 58.7 Difference 9.1
Grade 12 Students Not Taking Science	Male 66.7 Female 56.3 Difference 10.4	Male 46.2 Female 41.4 Difference 4.8

FIGURE 15

SCIENCE TEACHING AND LEARNING VARIABLE CORRELATIONS WITH MEAN SCORE ON FIFTH GRADE INTERNATIONAL CORE TEST

Variables Arranged in Descending Order of U.S. Correlations

Variables	U.S. Correlations	Japan Correlations
Books in the home	.244*	.253*
Students view of importance of science	.233*	.090*
I like science	.200*	.088*
Ease of learning science	.192*	.173*
Use textbooks	.153*	.114*
Have science tests	.133*	.147*
Students do experiments	.093*	.118*
Teacher makes lessons interesting	.093*	.051*
General quality of school life	.024*	.144*
Use library books	-.002	-.089*
Students do lab in small groups	-.012	-.152*
Watch teacher do experiments	-.039*	-.099
Teacher uses ideas	-.095*	-.082
Choose topics for study	-.102*	-.218*

* Indicates significance at the .05 level.

FIGURE 16

SCIENCE TEACHING AND LEARNING VARIABLE CORRELATIONS WITH
MEAN SCORE ON NINTH GRADE INTERNATIONAL CORE TEST
Variables Arranged in Descending
Order of U.S. Correlations

Variables	U.S. Correlations	Japan Correlations
Ease of learning science	.338*	.273*
Books in the home	.295*	.292*
I like science	.285*	.287*
Students do experiments	.255*	.039*
Student view of importance of science	.248*	.119*
Students do lab work in small groups	.240*	.092
Write up lab reports	.226*	.026
Career interest in science	.194*	.133*
Homework on all subjects	.185*	.257*
Teacher gives instruction for lab work	.174*	.081
Adoption of scientific attitude	.134*	.162*
Use hand calculators	.105*	-.174
General quality of school life	.101*	.118*
Teacher makes lessons interesting	.098*	.119*
Use textbooks	.095*	.030
Have science tests	.074*	.188*
Watch teacher do experiments	.064*	.070*
Field work outside classroom	.049*	.008
Hours science homework	.047*	.162*
Teachers help with difficulties in science	.043*	.082*
Use library books	.030	.006
Teacher explains relevance	.017	.035
Teacher discusses careers	-.053*	-.077
Students work on problems with teacher	-.151*	-.060
Students work on problems own method	-.153	-.066

* Indicates significance at .05 level.

At the ninth grade level, there is a significant correlation of .105 with achievement in the U.S., while in Japan, there is a significant negative correlation of -.174. A Japanese view of the use of hand calculators is given by Masao Miyaki, "Calculators are not used in elementary and junior high schools so this contributes to helping children develop their mental abilities." (19)

There are a number of significant similarities and differences in student achievement in Japan and the United States. At all levels tested in the Second IEA Science Study, Japanese students scored higher on the science achievement tests. The differences were very small at the 5th grade level, but Japanese students scored much better in 12th grade physics. Japanese students tended to do better than their American counterparts on items classified as science process items. On logical thinking and integrated process skills tests administered to junior high school students in Hiroshima, Japan and North Carolina, Japanese students did better on all categories except one, where there was no difference. In both countries, males scored higher than females with the differences being greater in the U.S. than in Japan. In both countries, the differences were greater at the ninth grade level than at grade five. In both countries, students at all grade levels did better on the same items in 1983 than in 1970.

REFERENCES

1. Masao Miyake, National Report: Japan. Tokyo, Japan: National Institute for Educational Research, 1985.

2. Willard J. Jacobson, National Report: U.S.A. New York: Second International Science Study--U.S., 1985.

3. Masao Miyake, "Comparison with the First Study," Chapter 5 in National Report: Japan. Tokyo, Japan: National Institute for Educational Research, 1985, Fig 5-4.

4. Willard J. Jacobson and Rodney L. Doran, "The Second International Science Study: U.S. Results." Phi Delta Kappan 66 (February 1985), pp. 414-417.

5. Vantipa Roadrangka, Russell H. Yeany, and Michael J. Padilla, Group Test of Logical Thinking. Athens, Georgia: University of Georgia, 1983.

6. James R. Okey, Kevin C. Wise, and Joseph C. Burns, Integrated Process Skills Test II. Athens, Georgia: University of Georgia, 1982.

7. Floyd E. Mattheis, Willis E. Spooner, and Charles R. Coble, "A Study of the Logical Thinking Skills, Integrated Process Skills, and Attitudes of Junior High School Students in North Carolina," Greenville, North Carolina: East Carolina University, 1985.

8. Shigekazu Takemura et al., "A Study of Reasoning Skills in Junior High School Students (Grade 7-9)," Hiroshima, Japan: University of Hiroshima, 1985.

9. Ibid,, p. 9.

10. Ibid., p. 27.

11. Floyd E. Mattheis et al., "A Study of the Logical Thinking Skills, Integrated Process Skills, and Attitudes of Junior High School Students in North Carolina," p. 41.

12. Ibid., p. 41.

13. Ibid., p. 41.

14. L.C. Comber and John P. Keeves, Science Education in Nineteen Countries. New York: Wiley, 1973. p. 299.

15. Masao Miyake, "Summary of SISS Results," Chapter 4 in National Report: Japan. Tokyo, Japan: National Institute for Educational Research, 1985. Figures 4-6 and 4-13.

16. Willard J. Jacobson and Rodney L. Doran, "The Second International Science Study: U.S. Results." Phi Delta Kappan 66 (February 1985) pp. 414-417.

17. Masao Miyaki, "Figure 4-24 Student Questionnaire Variables with a Significant Difference in Correlation to Main Score on the Science Tests," National Report: Japan. Tokyo, Japan: National Institute for Educational Research, 1985.

18. Willard J. Jacobson, National Report: United States. Second IEA Science Study--U.S., 1985.

19. Masao Miyaki, "Why do Japanese Children Have Good School Results (particularly in mathematics and science)?" Memorandum. Tokyo, Japan: National Institute for Educational Research, 1985.

CHAPTER V

TEACHERS AND TEACHING - STUDENTS AND LEARNING

The significance of teachers and teaching for students and learning is stressed in the science education literature in both Japan and the United States. Major sources of information for this section are Japanese Government documents and data collected by the Second IEA Science Studies in the two countries.

What similarities and differences are there in teacher background and the ways that teachers teach in Japan and the United States? (1) (2) In the Second IEA Science Study, the teachers in the participating schools responded to a questionnaire which elicited information about them and their teaching. Strict comparisons are difficult, but on some of the questions there are fairly clear similarities and on others there are striking differences.

In both countries, the teachers of 5th grade, 9th grade and secondary school physics have similar patterns of college preparation. Most of the 5th and 9th grade teachers have had five to six years of college preparation. In both countries, the physics teachers have had more college preparation with a mode of seven or more years. With regard to the amount of science background, elementary school teachers in both countries reported that they had studied science but it was for less than 25 percent of their college education. In the United States, 67% of the responding physics teachers reported that more than 50 percent of their college education involved science subjects. Japanese 9th grade science teachers reported slightly less of a concentration on science subjects than the U.S. teachers. In both countries, the mode for teaching experience was 11 to 20 years, with ninth grade teachers and physics teachers being somewhat more experienced than their elementary school colleagues.

The teachers also reported on ways that teachers can keep up-to-date and improve their teaching. In both countries, the elementary school teachers seldom belong to a science teacher organization or a science association. In both countries, there are many teachers who do not belong to such organizations. In both countries, teachers occasionally read periodicals related to teaching in general, somewhat more so for elementary school teachers than others. In both countries, the teachers who specialize in science are more likely than their elementary school colleagues to read periodicals on science subjects. In the United States, for example, 83 percent of the physics teachers report reading a science periodical each month or more often. Japanese teachers appear to devote more time to in-service education with an estimated two to three days a year. More than 70 percent of the elementary school teachers in the U.S. report less than one day of in-service during the past year. In both countries, junior high school science teachers report devoting more time to in-service education than teachers at other levels.

There are both similarities and differences in approaches to teaching in the two countries. Teachers in both countries at each level report that they use question-and-answer methods. Similarly, teachers in both countries at the elementary and junior high school levels report that they "occasionally" lecture, but the 12th grade physics teachers lecture "frequently." Teachers in both countries tend to depend on the textbook to determine what to teach. In both countries, audio-visual materials are used more often in the elementary school than in the junior or upper secondary; somewhat greater use of audio-visual materials is reported from the United States than from Japan. In both countries, most of the teachers report that field trips are "rarely" or "never" used. When used, field trips are more likely to take place in the elementary school than at other levels. Japanese teachers are somewhat more likely to divide their classes into small groups, and they do it more frequently in the elementary school than in the upper secondary school. In the United States, almost all students receive the same assignments. While this is the most widely used approach, there is a somewhat greater likelihood in Japan that some students will be given different assignments. Perhaps because it is a centralized school system, Japanese teachers are more likely to use standardized tests. American teachers are more likely to use teacher-made objective (short answer) tests. Japanese teachers, especially grade 12 physics teachers, make more use of teacher-made essay tests. U.S. teachers, especially at the junior high school and grade 12 physics level, are more likely than their Japanese counterparts to use homework assignments or laboratory exercises and projects in assessing the work of their science students.

What kind of educational preparation is required of teachers? (3) Teachers in Japan must be certified, and the teacher certificates are granted by prefectural boards of education.

There are two kinds of certificates: temporary and regular. Regular teaching certificates are valid in all prefectures and are valid for life. Temporary certificates are honored for three years only and are valid only in the prefecture by which they were issued. Since it is reported that there are many more applicants for teaching positions than there are positions available, only the programs of preparation for the regular teaching certificates will be described.

A bachelors degree or its equivalent is required of all teachers. Teachers in the upper secondary school are expected to have a masters degree or 30 credits beyond the bachelor's degree. In their preservice training, prospective teachers are required to take work in general education subjects and in professional and specialized subjects. In general education, 12 credits each are required in the humanities, social sciences, and natural sciences. There is also a requirement of eight credits in foreign languages and four credits in health and physical training. To become a science teacher in lower or upper secondary school, a total of 40 credits in science are required, including credits for physics and physics laboratory, chemistry and chemistry laboratory, biology and biology laboratory, and earth science and earth science laboratory. This can be compared with a State such as New York, where 36 credits in science are required with at least 15 credits in the science that is to be taught and collegiate-level study in at least two sciences. In professional studies, the future Japanese teachers are required to take work in Pedagogical Theory, Educational Psychology, Teaching

Materials, Methods of Teaching a Subject, Teaching Practice, Moral Education, and Electives. These requirements are somewhat more specific than those in a state such as New York, where 12 semester hours in professional study of education and a college supervised student teaching experience are required.

Figure 17 gives the "Types of Teacher Certificates and Qualifications Thereof." (4) The "Minimum Requirements for Teacher Preparation" in terms of types of courses are given in Figure 18.

How are new science teachers in Japan solicited and hired? The teacher must be certified to teach. Teaching certificates are granted by the Prefectural Boards of Education. The description of how individuals prepare themselves to obtain teacher certificates is described in the section on teacher preparation.

How teachers are appointed is described in a book, Education in Japan, prepared by the Research and Statistics Division of the Ministry of Education, Science and Culture. (5) There is no mention of such American procedures as advertising a vacancy, submitting a letter of application and interviews by potential colleagues, and demonstration teaching, although others report they are used.

Teachers in all prefectural schools and in all municipal schools, except kindergartens and full-time upper secondary schools, are appointed by prefectural boards of education. The applicants take appointment examinations. The appointments are then made by the prefectural superintendent of education on the basis of the results of the appointment examination.

What are the functions of in-service teacher education? (6) "...for educational public service personnel, in-service training is compulsory as it is considered indispensable for the performance of their duties." (7) The prefectural boards of education have the primary responsibility for in-service training. These prefectural boards of education, with state subsidies, organize in-service training for new teachers, which may last for 20 days or more and consists of both general and practical training. For teachers with five or more years experience in teaching, in-service training lasting for six days per year is provided involving lectures and studies and discussions on teaching. In science education, much of this in-service education is conducted by the Science Education Centers. There are Science Education Centers in each of the prefectures.

In-service training includes general culture and education and professional education. Under professional education, two of the most widely studied topics are "teaching method by subject area" and "study on teaching materials." Under general culture and education, two topics dealt with are "thoughts to bear in mind on education" and "ethics and concepts of service for teachers."

Much of the in-service education takes the form of lectures. This is often combined with seminars on classwork. Training is usually carried out during the summers and first terms.

FIGURE 17

Types of Teacher Certificates and Qualifications Thereof

Types of Certificates		Basic Qualifications	Minimum Credits to be Obtained at Universities	
			Regarding Specialized Subjects*	Regarding Teaching Profession**
Elementary School Teachers	1st class	Bachelor's Degree	16	32
	2nd class	More than two years attendance at a university and more than 62 credits (2 credits should be in physical education).	8	22
Lower Secondary School Teachers	1st class	Bachelor's Degree	40	41
	2nd class	More than two years attendance at a university and more than 62 credits (2 credits should be in physical education).	20	10
Upper Secondary School Teachers	1st class	1. Master's degree or 2. Attendance of more than one year and obtaining more than 30 credits from the specialized course at university or its equivalent designated by the Ministry of Education.	62	14
	2nd class	Bachelor's Degree	40	14

* In lower and upper secondary schools, the number of credits required is different among specialized subjects. Therefore, only the case for the certificate in science is shown.

**Apart from the principles of education and educational psychology, teaching methods of each subject are included. Practice teaching is also required for obtaining teacher certificates.

FIGURE 18

Minimum Requirements for Science Teacher Preparation

General Education
- Humanities
- Social Sciences
- Natural Sciences

Foreign Language

Health and Training

Specialized Subjects Related to Teaching Subjects
- Physics and Physics Laboratory
- Chemistry and Chemistry Laboratory
- Biology and Biology Laboratory
- Earth Science and Earth Science Laboratory

Professional Subjects
- Pedagogical Theory
- Educational Psychology
- Study of Teaching Materials
- Teaching Method on Individual Teaching Subjects
- Teaching Practice
- Study on Moral Education
- Elective Subject

What are the Science Education Centers? What are their functions?

(8) Science Education Centers are among the most important organizations concerned with science education in Japan. The main objectives of the Science Education Centers are to re-educate teachers and to carry out science education research on such topics as teaching materials, teaching techniques, and educational aids. Compared to the more or less academic studies of universities, the Science Education Centers aim at the advancement of science education from a more practical point of view.

For teachers, the Science Education Centers provide in-service programs. They deal with such topics as teaching materials and techniques, the production and operation of educational aids, the safe handling of chemicals, and guiding children's voluntary studies or inventions. They also organize lecture series, which are usually given by university staff members.

Some Science Education Centers provide "A Science Room for Children." Here, children are guided to have experiences in science and to have the pleasure of making tools and toys. The Centers encourage and commend voluntary studies on the part of children. Occasionally, they hold exhibitions of the children's work.

The Centers bring essential teacher aids and educational materials to remote schools so that students in these remote schools can have suitable science programs.

There are annual meetings where representatives of the Centers exchange ideas and discuss the results of studies.

In the United States, there are many organizations, such as museums, zoos, botanical gardens, nature centers, and teacher centers that make important contributions to the science education of children and provide in-service education opportunities for teachers. While these institutions carry out many of the same functions as the Japanese Science Education Centers, there is no nation-wide system of Centers that provides support for teachers, special opportunities for children and young people, conducts science education research, and disseminates the results of studies. A brief description of the Science Education Center in Hiroshima will indicate the kinds of resources that are made available at the Hiroshima Science Education Center. There are many similarities between this Center and the 49 others in Japan.

The Hiroshima Science Education Center is housed in a three-story building. In the Center there are study rooms, laboratories, and preparation rooms for physics, chemistry, biology, and earth science. There is an astronomical observatory (dome), planetarium, greenhouse, and library for teaching materials. In addition, there is a big lecture hall, an audio-visual research room, and a library.

The Center has a staff of 15:

1 Director
2 Chiefs (general affairs and in-service training)

7 Researchers (elementary science, physics, chemistry, biology, and earth science)
4 Clerical staff members

In addition to these contributors, in 1981 for example, the Hiroshima Science Education Center sponsored 153 lectures attended by 2,584 participants.

The Science Education Centers are important institutions for the continued improvement of science education programs. There are about 50 Centers and there is at least one in each perfecture. They are linked nationally through publications and annual meetings. They share experiences and learn how to better carry out their functions.

How do student backgrounds and expectations for the future in Japan and the United States compare? In the Second International Science Study (SISS), students in Japan (9) and the United States (10) responded to a questionnaire soliciting information about their backgrounds. Some of their responses are now available and may be interesting and possibly illuminating.

Sex. As might be expected, about half the students in grades five and nine are male and one half are female. But, in the U.S., 63% of the students in 12th grade physics courses are male; in Japan the comparable figure is 68%. In the 3N population, which is 12th grade students who are not studying any science, in the U.S. 56% are female compared to 65% female in Japan.

Family size. The students where asked, "How many brothers and sisters do you have?" American families tend to be larger. In both countries, the largest percentage of students had one brother or sister: Japan 22% and the U.S. 24%. But, 17% of the U.S. students replied that they had four or more siblings as compared to 5% in Japan.

Like Science. They were asked whether they liked science more, about the same, or less than most other subjects. There were similar reactions to this question in both countries. In Japan, about 35% of the students said that they like science better than other subjects as compared to 31% in the U.S. But, 23% in both countries liked science less than other subjects.

Future science education. The students were asked about plans for further education, including science education. In both countries, almost all of the students expected to complete year 12 of the secondary school. Many more Japanese ninth graders than U.S. ninth graders (48% to 11%) did not expect to go on beyond high school. However, the 12th grade students studying science in the U.S. set their sights high with 55% of the students expecting to complete more than four years of study after high school; the comparable figure in Japan was 13%. However, 57% of the Japanese 12th graders studying science expect to have three to four years of post-secondary school study. Of the 12th grade students studying science, 85% in the U.S. and 61% in Japan expect to include science subjects in their further education.

Homework. In some studies, a positive correlation has been found between the amount of time devoted to homework and achievement. The students were asked, "About how many hours a week do you usually spend on homework?" The Japanese students, with a mean of 3.9 hours, reported somewhat more homework than the U.S. students, who had a mean of 3.2 hours. In both countries, the 12th grade students studying science were the students who reported the most homework with a mean of 4.4 hours in Japan and 3.5 hours in the U.S.

The students were also asked, "How many hours a week do you usually spend on homework or other schoolwork out of class for science subjects?" Here, the mean of 2.4 hours in the U.S. was more than the Japanese mean of 2.1 hours. Again, the 12th grade students studying science reported the most science homework with a mean of 2.6 hours in Japan and 2.5 hours in the U.S.

Books in the home. Another variable that has been found to correlate with individual achievement is the number of books in the home. The students were asked, "How many books are there in your home?" The mode reported by Japanese students was 26-100 books. The mode reported by the U.S. students was 101-250 books. In both countries, 12th grade students studying science reported the most books in the home.

There are many similarities in teachers and teaching, students and learning in Japan and the United States. In both countries, a Bachelor's degree or its equivalent is necessary for appointment as a teacher. Japanese teachers in the upper secondary school as well as many American teachers will have a Master's degree or more. The Japanese teacher education program seems to include somewhat more professional courses. The importance of in-service education is recognized in both countries. The Japanese have developed Science Education Centers that apparently make important contributions to in-service teacher education. In both countries, teachers use textbooks and audio-visual materials. Japanese teachers, especially in grade 12, are more likely to use standardized tests.

REFERENCES

1. Masao Miyaki, National Report: Japan. Tokyo, Japan: National Institute for Educational Research, 1985.

2. Willard J. Jacobson, National Report: United States. Second IEA Science Study, 1985.

3. Adapted from Shigekazu Takemura, Study on Position of Science Education in Japan. pp. 57-59.

4. Masao Miyake, "Type of Teacher Certificates and Qualifications Thereof." National Science Curriculum Case Studies. Tokyo, Japan: National Institute for Educational Research, 1985, p. 10.

5. Research and Statistics Division, "How are Public School Teachers Appointed," Education in Japan. Tokyo, Japan: Ministry of Education, Science and Culture, 1980. pp. 80-81.

6. Section for Educational Cooperation in Asia, In-Service Training for Teachers in Japan. NIER Occasional Paper 02/85. Tokyo, Japan: National Institute for Educational Research, 1985.

7. Ibid., p. 2.

8. Shigekazu Takemura, Study on Position of Science Education in Japan. pp. 67-69.

9. Masao Miyake, National Report: Japan. Tokyo, Japan: National Institute for Educational Research, 1985, pp. 9-16.

10. Willard J. Jacobson, National Report: U.S.. New York: Second IEA Science Study--U.S., 1985, pp. 9-16.

CHAPTER VI
SCHOOL, TECHNOLOGY, AND SCHOOL REFORM

There is a growing amount of literature in English on Japanese schools and schooling. The Japanese Ministry of Education, Science and Culture has made an important contribution by having a number of important books and papers translated into English. These have been important sources for this analysis. The Second IEA Science Study used a school questionnaire that elicited information about schools. Articles criticizing Japanese education and calling for reform have been consulted and some of the possible implications for science education have been noted.

What similarities and differences are there in schools in Japan and the United States? (1) (2) Japan has a centralized school system in which the schools tend to be alike throughout the system. In the United States, education is decentralized, with much of the authority resting in the states and communities within states. In the Second IEA Science Study, there was a "School Questionnaire." The responses to some of the questions in this questionnaire elucidate some of the similarities and differences in schools in the two countries.

In both countries, most elementary school teachers are female. There was a higher percentage of female teachers in the U.S. than in Japan. In the U.S., the mean number of female teachers in the reporting schools was almost five times as great as that for male teachers. Of all teachers in the junior or lower secondary schools in Japan, there are substantially more male than female teachers. In the U.S., they are roughly equal in number. Of all teachers in grade 12 in Japan, there are many more male teachers, while in the U.S., there are only slightly more male teachers than female.

In both countries, there are more male science teachers. At the 9th grade level in the U.S., the schools reported a mean of four male science teachers per school and a mean of two female science teachers per school. The ratio of male to female for science teachers in the 9th grade in Japan was even greater. In both countries, the preponderance of 12th grade physics teachers is male. Again, the proportion of male to female physics teachers is considerably greater in Japan than in the U.S.

The Japanese report more hours of school per week. Almost all U.S. schools have a school week within the range of 26 to 35 hours. At all levels, the Japanese report a mean of more than 37 hours of school per week.

A preponderance of U.S. schools report a school year 171 to 180 days. This is considerably less than the reported Japanese school year, which has about 240 days.

Although it obviously could be a function of the size of the schools, U.S. respondents reported that more rooms in their schools are equipped for science teaching and/or student laboratory work. The bulk of the U.S. respondents reported that their science rooms are used more than 80 percent of the week for science lessons or laboratory work. The Japanese reported somewhat less utilization of science rooms for science instruction. Curiously, in Japan in 12th grade physics, the science rooms or laboratories are used less for science than at the 9th grade level. However, this may be because in Japan science rooms are usually used only for laboratory work.

Both countries report that they have practically no science laboratory assistants or technicians. At the 9th and 12th grade levels in both countries, science equipment is selected by a teacher or group of teachers.

At each level in the U.S., textbooks are usually selected by a teacher or group of teachers. This is also true at the 12th grade level in Japan. However, at the elementary and lower secondary levels in Japan, the textbooks are more likely to be selected by a central authority. In both countries, it is reported that parents and teachers become involved in activities to raise money for schools.

Discussions of general policies for school organizations or curriculum involving both parents and teachers are much more likely to take place in the U.S. than in Japan. In neither country are groups of parents and teachers likely to become involved in such science-related activities as science fairs and industry visits.

How do the opportunities to learn specific concepts in school differ in Japan and the United States? It should be remembered that the Japanese school year (about 240 days) is longer than the U.S. school year (about 180 days). It may be that the assignments given Japanese students to complete during the summer holidays are also important. Not only are Japanese students given opportunities to learn new materials, but they may also be discouraged from "forgetting" half of what they have learned during the past school year.

In the Second International Science Study (SISS), the teachers of the tested students were asked to indicate the opportunity that the students had had to learn the concept indicated by each item. Because the opportunity-to-learn data were collected and interpreted in slightly different ways, the mean opportunities to learn in Japan and the United States cannot be directly compared. However, interesting insights can be gained by identifying the 10 items on which students did best and the 10 items for which students had the best opportunity to learn.

In Japan (3), of the 10 items on which fifth grade students did best, eight of these are also on the list of the 10 items on which the students had the greatest opportunity to learn. This could indicate a fairly strong relationship. In the United States (4), of the 10 items on which fifth grade students did best, five were on the list of 10 items on which the students had the greatest opportunity to learn. This would seem to indicate a somewhat weaker relationship between achievement and the opportunity to learn in U.S. schools.

At the ninth grade level, there were no OTL-achievement correlation differences between Japan and the United States. In the core test, there were 30 test items. The 10 items with the highest achievement and the 10 items with the highest opportunity to learn were identified. In both countries, there were five items that were on both the list of 10 items with the highest achievement scores and the list of 10 items with the highest opportunity to learn.

In general in IEA science studies, there has been a fairly high correlation between science achievement and opportunity to learn. In Japan and the United States, the mean science achievement scores for grade five and grade nine were quite similar. There apparently is also considerable similarity between the opportunity to learn scores.

How do entrance examinations affect science education? It has been pointed out that, "...one of the central and most persistent forces driving Japanese students to high performances is the college entrance examination system. Today's high school education in Japan is largely dictated by the requirements of the entrance examinations." (5) There are examinations for entrance to some highly preferred upper secondary schools and for entrance to the most prestigious universities. Since entrance to and graduation from prestigious universities, or failure to gain entrance, can affect the student's entire life, many students and their families will devote a great deal of time, energy, and money to try to make it possible for students to gain entrance to preferred high schools which, in turn, may make it possible for them to enter a prestigious university. Many observers of Japanese education point to the entrance examinations and preparation for them as being key factors in Japanese education. While there are entrance examinations in the United States, their impact is not as deep and pervasive as in Japan. Discussions of the impact of entrance examinations in Japan can be found in articles by Nobuo K. Shimahara (6) and books by William K. Cummings (7) and Thomas P. Rohlen (8).

The entrance examinations have a wide impact upon education, including science education. (9) The nature of the university entrance examinations may have a greater influence on what science is actually taught than the course of study, and the university entrance examinations have become more and more difficult. A First-stage Standardized Achievement Examination (FSAE) has been introduced. It is claimed that the FSAE tests fundamental knowledge, general ability, and the science that students have studied in upper secondary school. The questions are composed by ten university professors for each subject. The FSAE becomes the first stage in entrance testing and the second stage is provided by the individual universities. Again, it is proposed that the First Stage Standardized Achievement Examination (FSAE) will be more influential on upper secondary school education than the course of study. However, there is movement toward a "Common Test." To help remedy "the evil effects of the competition for university admission," every university is requested to reform the content and methods of its entrance examinations.

How do Japanese students prepare for entrance examinations? (10) Most students of Japanese education agree that entrance examinations are an important aspect of Japanese education. Because it is very important to be admitted to a prestigious upper secondary school and from there into a top university, which can, upon graduation, lead to a good position in business and government, it is very important to do well on the entrance examinations. To try to improve chances on the examination, cram schools (juku) and tutoring services have been developed.

The cram schools (juku) have been an important industry providing supplementary education for a large fraction of Japanese students. Many of the juku are small and are operated by housewives and former teachers. However, some cram schools are large and diverse. They may be in franchise chains operated by publishing firms and department stores. The cram schools operate in the late afternoon and at night. Students and their families make great investments in time, energy, and money to use these services. There is concern about the impact of the juku upon the quality of adolescent life and the goal of equity in Japanese life. (11) Japanese science educators have agreed that the intensity of the cram schools and tutoring does affect science education in Japan. (12)

What out-of-school programs and resources in Japan contribute to science learning? (13) There is a wide range of out-of-school programs and resources in Japan that contribute to science education. It has been reported, for example, that science programs on television in Japan are more sophisticated than in the United States. (14) Chemical formulas and equations may be used in science programs on television. Opportunities to view more advanced science programs may be possible because of a more knowledgeable audience and, in turn, these more advanced television programs reinforce science learned in school. Similarly, science magazines and science kits are widely available. There are also science and natural history museums, zoos, botanical gardens, and science education centers. Many of these institutions and programs are similar to those in the United States. But, some are different and seemingly unique and might be considered for development elsewhere.

Science invention prizes. The importance of inventiveness and innovation are recognized in Japan. There is a concern that creativity be fostered. (15) To encourage inventions, there are annual science invention prizes. Among the prizes are "The Prime Minister Prize" and "The Encouragement Prize of the Minister of Education."

Science Education Centers. There are about 50 Science Education Centers in Japan. The primary function of these Centers is the re-education of teachers in elementary, junior high, and senior high schools, and to carry out science education research (see pp. 86-87). In addition, some of the Centers also set up "Science Rooms for Children." Among the aims are to help students experience a real interest in science and to give students the pleasure of making tools or toys independently. THe Centers encourage voluntary studies or inventions, and they sometimes hold exhibitions of the children's work.

Scientists in School Program. Several years ago, a "Scientists in Schools Program" was organized in New York City. It was a cooperative project of the New York City Board of Education, the New York Academy of Sciences, the National Science Foundation, and Teachers College, Columbia University. It proved to be an effective way for New York City children and teachers to have greater contact with scientists and engineers. A number of very exciting and rewarding science experiences occurred. The evaluations were positive and often glowing. Yet, to the best of our knowledge, few if any remnants of the program remain in New York City.

But, in Japan! In Hiroshima, there is a flourishing "Scientists in School Program." A wide variety of scientists come into the schools. Scientists participate in try-out lessons and engage in team teaching with school teachers. Some of these programs have already been recognized and have won prizes. The inauguration of the "Scientists in Schools Program" demonstrated the ability of the Japanese to recognize good ideas, adapt them to their settings, and eventually make them their own.

A number of problems associated with out-of-school activities have been identified. (16) Regardless of the out-of-school activities, the tremendous emphasis upon entrance examinations and preparation for them leads many pupils not to attend the out-of-school activities and, if they attend, they are so tired that they are generally inactive and appear uninterested. Few educators are well prepared to work with students in the study of nature, plant and animal nomenclature, and ecology. In the universities, the study of molecular biology, biochemistry, and biophysics has been emphasized at the sacrifice of taxonomy and morphology. Locations for field studies of nature are being destroyed by the construction of houses and factories.

How is technology used in the teaching of science? (17) Almost all of the elementary and secondary schools in Japan have the following instructional equipment:

slide projectors
8mm. sound-motion picture projector
16mm. sound-motion picture projector
over-head projector
tape recorder

This kind of equipment is also widely available in American schools. Video-cassette recorders (VCRs) and response analyzers are being installed. Many audio-visual associations and manufacturers produce science slides, films, transparencies, audio-cassettes, video-cassettes, charts, workbooks, and other instructional materials. The Science Education Centers have equipment that teachers can use to prepare instructional materials. Science programs are broadcast over radio and television.

Innovations and research on educational technology has been led by research in science education. (18) This research and innovation has had two major thrusts: the promotion of centers for educational technology and the improvement of education. A number of university centers have been established. Among other functions, they introduce technological approaches into methods of teacher education and try to improve education in the schools. Technology is being used to analyze the teaching/learning process and to design instructional approaches. The technology is used for the individualization of instruction and the development of means for dialogue between students and the instructional system. With research on educational technology in science education leading the way, a great deal of educational research and development has been stimulated.

How are textbooks developed and distributed? (19) In the United States, science textbooks are usually written by teams consisting of such professionals as scientists, science educators, classroom teachers, and sometimes media specialists. Often, the books are trial tested in schools. At one time, special projects or commissions were set up to improve the textbooks that children and teachers use. Eventually, the books are printed and distributed by textbook publishing firms.

It is often observed that most American textbooks at a given level or in a subject field are quite similar. The main reason is that publishers wish to sell as many books as they can. Textbooks are "adopted" by individual teachers, schools, school systems, or states. Sometimes, states, such as Texas and California, list books that have been approved or deemed acceptable, and teachers and schools can select books from these lists. The struggle for adoption by large states tends to lead to uniformity in the textbooks that are developed.

In Japan, textbooks are defined as, "books for pupils and students designed to be used by teachers as the main teaching materials for the subjects prescribed in the Course of Study, at elementary, lower and upper secondary schools or their equivalent." (20) As in most schools in the United States, students are provided with free textbooks. Only publishers designated by the Minister of Education, Science and Culture are permitted to publish textbooks for compulsory education schools, which are elementary and lower secondary schools. There is a move to make the same stipulation for the upper secondary schools.

The development, dissemination, and adoption of textbooks is somewhat similar to that used in some of the large states in the United States. However, the Ministry of Science, Education and Culture is much more deeply involved in this process than any federal agency in the United States.

The textbooks are prepared on the basis of the prescribed Course of Study and in accordance with the standards for textbook authorization. Original ideas may be added. The textbooks must be authorized by the Ministry of Education, Science and Culture, who is advised by The Textbook Authorization and Research Council. There are several hundred members of the Textbook Authorization and Research Council, including university professors and elementary and secondary school teachers. There are also textbook examination officers, who are full-time members of the staff of the Ministry; in 1983, there were 49 of them.

The textbook publishers submit lists of authorized textbooks. The Minister catalogs the books and sends the catalog to the various boards of education. The publishers send examination copies. The prefectural boards also set up councils for textbook selection, who advise adoption authorities on the selection of textbooks from the list of authorized textbooks.

Textbook publishing in Japan is a big enterprise. In 1983, there were 67 publishers, of which 25 publish textbooks for the compulsory education schools. About 200 million textbooks are needed each year in the elementary and secondary schools.

To what extent are electronic calculators used in science lessons? According to responses to the questionnaire in the Second International Science Study, very few ninth grade students in Japan use calculators. On a scale ranging from zero to three (0-3) for frequent use, the mean response for Japanese ninth grade students was 1.07. (21) In the United States, 42% of the ninth grade teachers reported that their students used calculators frequently or occasionally. (22) Although comparable data are not available for Japan, 98% of U.S. 12th grade teachers reported that their students used calculators.

How are microcomputers used in science education? (23) As in the United States, microcomputers are being used more and more in Japanese schools with interesting applications in science education. In the schools, the greatest use is in the upper secondary schools, with fewer uses in the lower secondary and elementary schools. Computer Assisted Instruction (CAI) is most popular in the elementary schools, where the computers are used for such functions as presenting teaching materials during class. In the secondary schools, Computer Managed Instruction (CMI) is most popular. Some examples of computer use in science education are individualized science study programs, presentation of the constellations, three-dimensional molecular models, and the calculation of calories in foods. At all levels, computers are also used in club activities.

Innovative uses of microcomputers in chemical education have been reported. (24) Using a student response mechanism where each student has a terminal, microcomputers were used to evaluate a new high school chemistry curriculum. This was a fast and efficient way of collecting student feedback before it could be "interpreted" by the teachers. The data collected and processed was used in the evaluation of a new chemistry program. Microcomputers are used to study dynamic phenomena, of which there are many in chemistry, such as the molecular vibration of the water molecule. They are also used for the study of electron densities using probability functions, such as the time dependent variable. This gives more meaning to probability than the traditional dotted cloud models shown in textbooks. Microcomputers are also used for communication between the student and computer. For example, the student can carry out titrations. After the end point is reached, the computer raises questions. If the response is wrong, the experimental conditions can be repeated.

The rapid increase in the availability of microcomputers makes more such experimentation possible in Japan as well as in the United States.

What have been the influences of United States science curricula and in what directions is Japanese science education moving? "Japanese people have always adopted, adapted, co-opted--or even borrowed the best from the West and East, yet sometimes discarded the borrowings to think and act according to their own unique characteristics." (25) In Japan, new science courses were designed that were in harmony with research and development in America. It has been suggested that innovations in science education in Japan were influenced in the 1960s by the introduction of materials from such American projects as the Physical Science Study Committee (PSSC), Harvard Project Physics (HPP), Chemical Bond Approach Project (CBA), Chem Study (CHEMS), and the Secondary Mathematics Study Group (SMSG). The conceptual structure of the disciplines was used in planning the curricula as was the inquiry processes that generate scientific knowledge. Attention was also given to the hierarchical concept of curriculum organization in the sequencing of learning materials.

> Innovation model was research development and diffusion. Academic background were behavioral psychology and pure science. Implicit value was competition. Relevance was seen in manpower-orientation and utilitarian consideration. Taxonomic domain was cognitive. Teaching technique was inductive-heuristic and stressed discovery methods. The teacher had the dominating role. The form of work organization was conventional class groups. Subject matter were linear disciplines. Mode of materials was highly structured. View of knowledge was subject disciplines. Humanity was viewed as manipulable and people were regarded as things. Evaluation techniques were tied to attainment of prespecified goals. The curriculum in science at all levels was organized around representative conceptual systems, their major supporting concepts, and the processes of science as they related to developing further economic growth. (26)

Certainly, this view is not consistent with the views of many of those involved in the American science curriculum projects in the 1950s and 1960s. Perhaps, one of the lessons that has been learned is that new science courses and materials will be viewed and used in many different ways. The views and uses cannot be foreseen.

It has been suggested that, while it was, in part, fruitful to imitate the American projects, it was a mistake to do so superficially, (27) because it led to the need to teach large quantities of more difficult knowledge. It has been alleged that "...curricula demanding voluminous knowledge and high-level quality increased the number of stragglers and pupils who disliked science..." (28) Contrary to the spirit of the innovators, laboratory work came to be neglected and the process of inquiry was taught by "dry" laboratories, using data shown in texts. More research and development in science education was undertaken in Japan. This involved teams of researchers and repeated tryouts of trial curricula to provide feedback that could be used for further improvement.

To correct the apparent inadequacies of the science curriculum of the 1960s and 1970s, a new orientation has been designed with the following broad objectives:

1. To develop the pupil's ability to think for himself and to cultivate creative intelligence and skills.

2. To develop a strong will power and to cultivate a self-reliant spirit.

3. To cultivate love and appreciation for nature and mankind.

4. To cultivate a proper attitude toward labor.

5. To cultivate practical sociability based on consciousness of solidarity and a spirit of service to the society.

6. To exert efforts to train a healthy and strong body.

7. To grow up into a Japanese citizen with love for people everywhere in the world in order to obtain the trust and respect of international society." (29)

In this new direction, we see the interesting emphasis upon the love and appreciation for nature and mankind, practical sociability, consciousness of solidarity and a spirit of service to society, and the concern for the trust and respect of international society. The effectiveness of Japanese education has been demonstrated. What will be the impact of these new directions upon the Japanese citizens of tomorrow who are in Japan's classrooms today?

What are some of the Japanese criticisms of their educational system including science education? (30) Teachers, schools, and the school system in Japan are being criticized. Education is considered to be very important, and, in part because of its importance, it is being subjected to critical discussion.

In March 1984, there was a Yomiuri Shimbun Opinion Survey on Education, in which 525 prominent members of society were polled (31). Seventy percent of the respondents said that compulsory education in Japan was being distorted by an over-emphasis on the school entrance examination system, and 60 percent lamented the absence of moral education in the classroom. The respondents were very critical of teachers with only 3 percent saying that today's teachers were better than in the past. There was great concern over juvenile delinquency. The most important approach to educational reform was held to be the improvement of the quality of teachers. It was suggested that the survey revealed a deep-seated dissatisfaction with the present education system in Japan.

Prime Minister Nakasone has made a seven-point proposal for educational reform:

1. To consider changing the present so-called "6-3-3" system.

2. Change the upper secondary school entrance examination system and discontinue reliance on test results as the main yardstick of students' academic success.

3. Change the university entrance examination system.

4. Promote such extracurricular activities as community service activities.

5. Reinforce moral education.

6. Encourage a more cosmopolitan outlook.

7. Improve the quality of the teaching staff. (32)

In the discussions and criticisms of Japanese education, there seems to be more emphasis on moral education and international or cosmopolitan education than there are in American criticisms and discussions of education. Since it is so important and influential in Japanese education, there is much discussion, generally critical, of the entrance examination system.

In most of the papers that have been made available, there is very little discussion of science education. The one exception is in a report from the Education Council of the Japanese Committee for Economic Development (33). While noting that the industrial strength of the nation is supported by excellent technologies involving application and development, they call for more attention to basic science. This requires creativity, and education should aim at tapping the creative ability of individuals at various levels of school education. They call for expansion of college science departments and the establishment of new educational institutions whose purpose is to foster creativity in science and technology. They also suggest that two or three national universities having science departments be linked with upper secondary schools. This would make possible early studies in an exclusive field, as well as to make more upper level courses available.

This committee of businessmen also suggest that in, "Education for the Information Society," more attention should be given to the use of computers in education. They see more computer utilization in the U.S., "...and it appears necessary that Japan catch up." They urge that a comprehensive plan be developed that would include educating software engineers and programmers, creating training programs for teachers, and developing educational materials that combine audio-visual materials and computers.

On September 5, 1984, Mr. Yasuhiro Nakasone, the Prime Minister of Japan, asked the Provisional Council on Educational Reform to advise him on "basic strategies for necessary reforms with regard to governmental policies in various aspects, so as to secure such education as will be compatible with the social changes and cultural developments of our country."(34) On June 16, 1985 they submitted a First Report on Educational Reform. (35) Their discussion of the "Basic Direction of the Educational Reform," "Major Issues to be Considered by the Council," and "Immediate Specific Proposals for Educational Reform" are far-ranging, and some of the discussion has implications for science education.

It is alleged that some of the confusion in education has something to do with a number of problems brought about by modern science and technology.

> Specifically, the development of modern science and technology has brought about the spread of materialistic ideas, the absence of feeling, an excessive emphasis on an empirical approach and on quantifiable values, a lack of reverence for the sublime, a loss of contact with nature, and a lack of due regard for the dignity of life.
>
> Further, it deserves notice that we are living in a civilization shifting from an energy-base to an information-base and the progress of the sophisticated information society has been giving people fewer and fewer opportunities for direct experience at first hand. The more diversified value systems and the wider generation gap have had a great impact on the growth and development of children. (36)

Obviously, these are challenging comments for those concerned about science education.

An important emphasis in the report is on the improvement of the quality of teachers. Because of the crucial role of teachers, "...the Council will consider overall strategies for improving the quality of teachers. All aspects--including training of teachers, both pre-service and in-service, appointment of teachers and evaluation of teachers's merit--will be considered as a whole." (37)

The Council recommends a six-year secondary school. Among the patterns of courses to be offered in the new type of secondary schools are:

> ...science and mathematics courses. This type of course would be meaningful in enhancing the abilities in science and mathematics of those students who have a deep interest in this area. A program of information science might be included as a course in this field. (38)

In Japan and the United States, education, including science education, is being criticized and proposals for reform are being made.

REFERENCES

1. Masao Miyake, National Report: Japan. Tokyo, Japan: National Institute for Educational Research. 1985.

2. Willard J. Jacobson, National Report: United States. New York: Second IEA Science Study--U.S., 1985.

3. Masao Miyake, National Report: Japan. Tokyo, Japan: National Institute for Educational Research. 1985, pp. 5 and 7.

4. Willard J. Jacobson, National Report: United States. New York: Second IEA Science Study--U.S., 1985, pp. 5 and 7.

5. Nobuo K. Shimahara, "Japanese Education and Its Implications for U.S. Education." Phi Delta Kappan 66 (February 1985) p. 419.

6. ________, "Socialisation for College Entrance Examinations in Japan." Comparative Education 14, No. 3, (October 1978): 253-266.

7. William K. Cummings, Education and Equality in Japan.. Princeton, N.J.: Princeton University Press, 1980, pp. 206-234.

8. Thomas P. Rohlen, Japan's High Schools. Berkeley, California: University of California Press, 1983. pp. 77-110.

9. Yujiro Nomura, "The Impact of Examination on Science Teaching in Japan," Journal of Science Education in Japan 4, No. 4, 1980, pp. 163-166.

10. Thomas P. Rohlen, "The Juku Phenomena: An Exploratory Essay," Journal of Japanese Studies 6. (1980): pp. 207-242.

11. Perhaps the best discussion of the examination competition and the struggle for equity in Japanese life is to be found in William K. Cummings, Education and Equality in Japan. Princeton, N.J.: Princeton University Press, 1980, pp. 206-234.

12. Communication from Masao Miyaki and Shigekazu Takemura .

13. Shigekazu Takemura, Study on the Position of Science Education in Japan. Hiroshima, Japan. Faculty of Education, Hiroshima University, 1984, pp. 73-80.

14. Kay Michael Troost, "What Accounts for Japan's Success in Science Education?" Educational Leadership. (December 1983/January 1984) p. 29.

15. Education Council, Japan Committee for Economic Development, "A Proposition from Businessmen for Educational Reform in Pursuit of Creativity, Diversity and Internationality," *Discussions on Educational Reform in Japan*. Tokyo, Japan: Foreign Press Center, 1985. pp. 35-42.

16. Kozo Imahori, "Out-of-School Science Activities in Japan at the Primary and Secondary School Level," *The Journal of Science Education in Japan*. 6, No. 2, 1982, pp. 47-58.

17. Shigekazu Takemura, *Study on the Position of Science Education in Japan*." pp. 55-56.

18. Masayuki Naruse and Masami Koganei, "Educational Technology in Japan." *Journal of Science Education in Japan* 3, No. 4 (1979) pp. 157-164.

19. Japan, National Institute for Educational Research, *The School Textbook System in Japan.* NIER Occasional Paper 04/84. Tokyo, Japan: National Institute for Educational Research, 1984.

20. Ibid., p. 1.

21. Masao Miyaki, *Japan, National Report*. Part 2. p. 26.

22. Willard J. Jacobson, *U.S. National Report*. Responses to questions on teacher questionnaire.

23. Japan, National Institute for Educational Research, *The Use of the Computer in Education in Japan*. NIER Occasional Paper 03/84. Tokyo, Japan: National Institute for Educational Research, 1984.

24. John T. Shimozawa, "Use of Microcomputers in Chemical Education." *The Journal of Science Education in Japan*. 5, No. 4. (1981) pp. 177-187.

25. Shigekazu Takemura, "People, Society and Science Education in Japan," in *Proceedings of U.S. - Italy Joint Seminar on Science Education for Elementary School Children*. Doris E. Hadary and Matilda Vicentini, eds. Washington, DC: The American University, 1983, p. 153.

26. Ibid., pp. 154-155.

27. Kozo Imahori, "Problems of Innovation in the Japanese Science Curricula," *Journal of Science Education in Japan*, 4, No. 4. 1980. pp. 139-148.

28. Ibid., p. 140.

29. Shigekazu Takemura, "People, Society and Science Education in Japan." pp. 155-156.

30. See Japan, Foreign Press Center, Discussion on Educational Reform in Japan. Reference Reading Center Series 15. Toyko, Japan: Foreign Press Center, 1985.

31. "Yomiuri Shimbun Opinion Survey on Education," Discussions on Educational Reform in Japan. Toyko, Japan: Foreign Press Center, 1985, pp. 25-29.

32. "Study of Educational Reform and Improvement of Entrance Examination System," Discussions on Educational Reform in Japan. p.13.

33. "A Proposition from Businessmen for Educational Reform in Pursuit of Creativity, Diversity and Internationality," Discussions on Educational Reform in Japan. 1985, pp. 41-42.

34. Japan, Provisional Council on Educational Reform, First Report on Educational Reform. Tokyo, Japan: Government of Japan. 1985, p. 15.

35. Ibid., p. 15.

36. Ibid., p. 21.

37. Ibid., p. 40.

38. Ibid., p. 57.

CHAPTER VII
SUMMARY, CONCLUSIONS, AND QUESTIONS

This monograph is an analysis and comparison of science education in Japan and the United States. The primary purpose of the analysis and comparison is to find ways to improve the experiences that children and young people in both countries have in science. "Japanese people have always adopted, adapted, co-opted--or even borrowed the best from the West and East, yet sometimes discarded the borrowings to think and act according to their own unique characteristics." (1) A similar and related approach might be taken by the United States. Because of its great heterogenity in population and education, it is probably more important for the United States to study and come to know itself. But, based upon this knowledge of ourselves and our education, we should try to learn from others. Surely, we will improve if we study ourselves and others and "learn, adopt, adapt, extend, and grow." (2).

Similarities far outweigh differences in elementary school science curricula in Japan and the United States. There is an important emphasis in the elementary and lower secondary schools in Japan on developing a sensitivity to and love for nature. Developing a respect for life is also stressed. This dimension of science education is certainly present in U.S. elementary and junior high school science programs. The increased interest in environmental education in the U.S. has, in part, similar goals. However, these "humanistic" goals are not made as explicit in U.S. elementary science programs as they are in the Japanese.

There is greater variety in upper secondary school science programs in the United States than in Japan. In biology in the U.S., for example, programs have been developed that have had different emphases. One program emphasized an ecological approach, another an organismic approach, and yet another included more molecular biology. It may be that experimenting with a variety of approaches is more difficult in a centralized school system that is much influenced by entrance examinations. The importance of studying and adapting before adopting is underscored by Japanese criticisms of new American programs. The new American programs often emphasized inquiry. But, if they are not used in an inquiry mode, they can be nothing more than compendiums of facts to be read and memorized. This is certainly contrary to the aims of the program developers and does not contribute very much to the improvement of science programs anywhere.

The achievement scores at the fifth grade level in the two countries are very similar. However, at the elementary school level, we begin to see evidence of the effectiveness of the Japanese schools in developing science process skills.

At the ninth grade level, the Japanese students had scores on the IEA international core achievement tests that were slightly higher than those of the U.S. students. Again, the Japanese students did much better on items that have been classified as science process skill items.

At the 12th grade level, the Japanese students did slightly better on the international core test. But, on the 12th grade physics test! On the 30-item international physics test, the Japanese students had a mean of 17 items right, while the U.S. physics students had a mean of 10 items right. This is a very large difference in means. Certainly, U.S. educators and the public at large must be concerned about the comparatively low score of American 12th grade students in such an important field as physics.

Students in the 12th grade in the two countries who were not studying science were tested on a 30-item test containing items on science subjects that it would be desirable for future citizens to know. The 12th grade Japanese students had a mean of 17 right and U.S. students 15. While this difference is not as large as in physics, it can contribute to the concern over the adequacy of the American high school.

The differences in scores on two instruments assessing reasoning skills are striking and should cause concern. These instruments assess logical thinking and integrated process skills. On every category, the Hiroshima lower secondary school students did better than their counterparts in North Carolina. Why? Most of the new elementary and junior high school science programs in the United States have as one of their goals the development of science process skills. Are these new programs being used? Are they being used as they were intended? Are American elementary and junior high school students actually having as many "hands-on," "minds-on" science experiences as are called for in modern science programs? Certainly, these results in critically important areas should be investigated further.

In both countries, males tend to do better on science achievement tests than females. The differences are greater in the United States than in Japan. Disturbingly, the differences at the ninth grade level are greater than at the fifth grade level. In the United States, the differences between sexes on the 12th grade core tests were even greater. Thus, it appears that the sex differences in science achievement scores tend to increase as the grade level increases. Both Japan and the United States face a challenge to improve the science achievement of females.

A major reason that Japanese students tend to score better on various kinds of achievement tests may simply be that more time is devoted to education, roughly 240 days to 180 days. Some American observers in Japanese schools have also suggested that during the usual school day, Japanese students and teachers actually spend more time in teaching and learning. The special testing and coaching schools, jukus, also contribute. As a Japanese colleague has said, "In the coaching schools, Japanese students learn what has to be learned to score well on tests."

An interesting innovation is to start the school year in April, before the summer holidays. The teachers then can make assignments for the summer holiday months. The students return to the same teacher in September, and this teacher can assess, consider, and discuss the summer assignment. An American observer has suggested that the summer assignments, checked by the same teacher as the student has in the spring, may keep students from "forgetting half of what they have learned during the year."

The high school is a problem. There is not a great difference between the achievement scores of Japanese and American students at the fifth and ninth grade levels. But, the differences in scores on the basic high school physics tests are striking. There are many who believe that education in physics is of special importance for young people. In fact, some knowledge of physics is helpful, perhaps essential, in learning other sciences. Only a small percentage of U.S. high school students elect to study physics. Those who do choose to study physics did not do very well on an international physics achievement test when compared with Japanese students. Physics is so basic and the achievement of U.S. physics students is so poor that it would seem essential that something be done to improve high school physics in the United States.

Teacher education in science is quite similar in Japan and the United States. In general, a bachelors degree is required of all teachers. In some states in the United States and for upper secondary schools in Japan, a masters or its equivalent is required. In the Japanese teacher education, there seems to be somewhat more attention given to such professional subjects as pedagogical theory, educational psychology, and methods and materials of teaching. It appears that in Japan, more attention is given to in-service teacher education. In both countries, questions are raised as to what kind of in-service education is the most useful.

In Japan, there is greater emphasis on entrance examinations and preparation for them. Students and their families devote a great deal of time, money, and energy to preparation for the entrance examinations. These entrance examinations and preparation for them are being subjected to searching criticism by groups that are proposing reforms in Japanese education.

There are interesting and perhaps important similarities and differences in student backgrounds in the two countries. In both countries, more males than females elect science in the 12th grade. Roughly, the same percentage of students in the two countries say they like science better than other subjects. Exactly the same percentage of students in the two countries responded that they liked science less than other subjects. Japanese students reported somewhat more hours a week devoted to homework, but in both countries it was the 12th grade students studying science who did the most homework. U.S. students reported the presence of more books in the home. In both countries, almost all students expect to complete year 12 of the secondary school. Substantially more American 12th graders expect to complete more than four years of study after high school. More U.S. 12th grade students expect to include science subjects in their further education.

There seems to be general agreement that continuing education or in-service education is essential for teachers, perhaps, especially for science teachers. In fact, continuing in-service education in Japan is mandated. Some of the in-service education of teachers of science takes place in Science Education Centers. While there are many institutions in the United States engaged in continuing education, there are few, if any, that are strictly comparable to the Japanese Science Education Centers. Japanese studies indicate that these Centers are very active in science education, and American observers tend to agree that these Centers make important contributions.

Educational technology, such as audio-visual equipment, is widely used in both countries. Electronic calculators apparently are much more widely used in the U.S. than in Japan. Teachers of the 12th grade in the U.S. reported that almost all of their students used calculators. There is a difference of opinion about their use. There is the opinion in Japan that using calculators may hinder the development of children's mental abilities.

Searching examination of educational policy, widespread criticisms, and calls for reform of science education are to be found in both Japan and the United States. In some of the discussions in Japan, there seems to be considerable criticism of modern science and technology and moral and humanistic education is stressed. (3) Some critics seem to be on the verge of calling for less emphasis on certain aspects of scientific and technological education. In the United States, the Commission on Precollege Education in Mathematics, Science and Technology has called for higher requirements in mathematics and science in the high school. (4) It is important for both countries to monitor the policy examinations, critical analyses and calls for reform in the other countries. It would certainly be unwise to adopt practices from another country when educators and policymakers in that country are questioning the practice. For example, it may very well be that entrance examinations and intensive preparation for these examinations contribute to the high achievement scores of Japanese students. But, anyone considering the adoption of this practice should become aware of the Japanese experiences and the criticisms that educational reformers are making of the entrance examinations, the intense preparations for them, and the price that is paid by students and their families.

Intensive science curriculum development took place in the United States from the late 50s to the early 70s. This intense activity led to the development of several new programs at the elementary, junior high school, and senior high school levels. Of course, these new programs came to the attention of Japanese science educators. Some were adopted, more adapted, and some tried. Apparently, there have been few overall evaluations of the effectiveness of these new programs in Japan. But, at least one report suggests that the implementation of the parts of one program led to effects that were quite contrary to those anticipated by the developers of the program. The textbooks and other materials in the new programs were often intended to stimulate and develop students' inquiring abilities. But, the materials contained a great deal of modern scientific knowledge that previously had not been in science programs. One Japanese critic has stated that this just provided more information to be assigned and memorized. An examination of Japanese science curricula suggest that there is very little of these new programs in these curricula. Perhaps, the word "adapt" is of special importance when innovations from other cultures and educational systems are considered.

"Know yourself--then study, learn, adapt, extend and grow." It is almost a truism, but extremely important, that the characteristics of the society and culture be considered in the development of science education. (5) For example, one of the reasons that Japanese schools have more time for teaching and learning is that they have a five-and-a-half day school week. A quick response from an American critic might be that American students and their teachers should go to school five-and-a-half days a week. But, many, including many students and teachers, argue that this would be a mistake in the United States. They contend that a much more effective way in the United States is to give greater encouragement and support to the wide range of voluntary activities that take place on Saturdays--from honors programs in universities to ecological studies at the local nature center. For American students, teachers, and societies, these voluntary approaches to further study in science may be more effective. Certainly, we can learn much from the study of science education in Japan. But, for a large country with a heterogenous population and decentralized education, it may be especially important to "know yourself." Then, American educators can "learn, adapt, extend and grow."

QUESTIONS

Among the most important outcomes of any investigation are the questions that are raised. The following are among the questions that deserve further thought and investigation:

1. Why are the Japanese schools more effective in developing science process skills? The development of science process skills has been a major emphasis in new science programs in the U.S., but the Japanese students score consistently higher on tests of these process skills. Why?

2. To what extent are school assignments for the summer that are considered, assessed, and discussed by the same teacher as the student has in the spring an effective way to increase the amount of time and energy a student devotes to education?

3. What can be done to improve high school physics education in the United States? The differences in achievement in upper secondary school physics in Japan and the U.S. are striking.

4. How can the science achievement of females be improved? In both Japan and the United States, males have higher science achievement scores than females. The differences are greater in the ninth grade than in the fifth.

5. What kind of in-service education is most helpful for teachers who teach science? Exploration is going on in the Science Education Centers as to what kinds of in-service teacher education are effective. Continuing in-service education is viewed as being essential in both countries.

6. To what extent are the Japanese Science Education Centers effective? What can be learned from this experience?

7. How can science educators in Japan and the United States monitor developments in both countries so that both can learn from the other's criticisms and adaptations, failures and successes?

REFERENCES

1. Shigekazu Takemura, "People, Society and Science Education in Japan," in Proceedings of U.S.-Italy Joint Seminars in Science Education for Elementary School Children. Doris E. Hadary and Matilda Vicentini, eds. Washington, DC: The American University, 1983. p 153-

2. Some of the suggestions included in this chapter are drawn from a memorandum, "Why do Japanese Children Have Good School Results (particularly in mathematics and science)?" prepared by Masao Miyaki, the Japanese National Research Coordinator for the Second IEA Science Study--Japan.

3. Japan, Provisional Council on Educational Reform. First Report on Educational Reform: Tokyo, Japan: Government of Japan, 1985. p. 21.

4. National Science Board Commission on Precollege Education in Mathematics, Science and Technology. Educating Americans for the 21st Century. Washington, DC: National Science Foundation, 1983. pp. 39-41.

5. This point is developed further in Willard J. Jacobson, "Science Education for the 21st Century--The Great Debate," New York: The Second International Science Study, 1984.

BIBLIOGRAPHY

Abe, Kozi. "The Japan Information Center of Science and Technology and Its Activities." Aslib Proceedings 11 (November 1959).

Abracia, Efrain E. "Science in Japanese Compulsory Education." Unitas 39 (March 1966):112-122.

Anderson, Alun M. "The Great Japanese I.Q. Increase." Nature 297(20 May 1982):180-181.

Anderson, Ronald S. Education in Japan: A Century of Modern Development. Washington, D.C.: U.S. Government Printing Office, 1975.

Armstrong, Ronald E. "A Proposal for US-Japan Cooperative Research on Learning to Learn in the Earth Sciences." Paper presented at the US-Japan Seminar, Washington, D.C., 16-22 November 1985.

Aso, Makoto and Amano, Ikuo. Education and Japan's Modernization. Tokyo: The Japan Times, 1983.

Beauchamp, Edward R., ed. Learning to Be Japanese. Hamden, Conn.: Linnet Books, 1978.

Beauchamp, E.R.; Adward, R.; and Rubinger, R. Education in Japan: A Source Book. New York: Garland Publishing Co., (in press).

Birnbaum, H. "Japanese Educational Patterns in Science and Engineering." Science 181 (28 September 1973):1222-1227.

Bonn, George S. (compiler). Japanese Journals in Science and Technology: An Annotated Checklist. New York: New York Public Library, 1960.

Burnell, Jerrold B. "Japan: Why It Hasn't Happened." Environmental Education Report and Newsletter 13 (October 1984-January 1985): 17-18.

Comber, L.C. and Keeves, John P. Science Education in Nineteen Countries. International Studies in Evaluation I. Stockholm: Almqvist and Wiksell, 1973.

"Compulsory Education Draws 99.98% National Attendance - 1980 Education White Paper Published." Japan Report, no. 11, 1981, p. 3.

Council for Science and Industrial Education. "The Spirit of Science Education." Science Education in Japan. Tokyo: Japanese National Commission for UNESCO, 1968, pp. 107-113.

Cummings, William K. Education and Equality in Japan. Princeton, N.J.: Princeton University Press, 1980.

Discussions on Educational Reform in Japan. Reference Reading Series, no. 15. Tokyo: Foreign Press Center, 1985.

Easley, Jack. "An American Method of Teaching, Developed in Japan and Transplanted Back into America." Paper presented at the US-Japan Seminar on Science Education, Washington, D.C., 16-22 November 1985.

Education Council, Japan Committee for Economic Development. "A Proposition from Businessmen for Educational Reform in Pursuit of Creativity, Diversity and Internationality," Discussions on Educational Reform in Japan. Tokyo, Japan: Foreign Press Center, 1985, pp. 35-42.

Education in Japan. "About Japan" Series, no. 8. Tokyo: Foreign Press Center, 1978.

Education in Japan. The International Research Institute, Hiroshima University. Vol. 1. Development of Educational Thoughts in Japan.

________. Vol. 2. Educational Systems in Japan.

________. Vol. 3. Curriculum Development in Elementary Education.

________. Vol. 4. Curriculum Development in Secondary Education.

________. Vol. 5. Social Education.

________. Vol. 6. Education for Women.

________. Vol. 7. Educational Technology.

________. Vol. 8. Educational Reforms.

________. Vol. 9. Controversial Issues in Education.

________. Vol. 10. Educational Research in Japan.

Educational Statistics in Japan. NIER Occasional Paper 03/85. Tokyo: National Institute for Educational Research in Japan, 1985.

Ferguson, Patrick. "Teacher Education in Japan: An Historical and Comparative Perspective." Journal of Teacher Education 36 (September - October 1985): 20-24.

Fetters, W.B., et al. "Schooling Experiences in Japan and the U.S.: A Cross-National Comparison of High School Students." Paper presented at the 1983 Annual Meeting of the American Educational Research Association in Montreal, 13 April 1983.

Feltham, Wendy. "Life Lab's Cross-Cultural US/Japan Sister Schools Project." Paper presented at the US-Japan Seminar on Science Education, Washington, D.C., 16-22 November 1985.

Fiske, Edward B. "Education in Japan: Lessons for America." New York Times, 10, 11, 12, 13 July 1983.

Frankel, Martin M. and Gerald, Debra E. Projections of Education Statistics to 1990-91. Vol. 1: Analytical Report. Washington, D.C.: National Center for Education Statistics (NCES 82-402-A), 1982.

Fujimoto, Haruyoshi. "Earth Science Education in Secondary Schools." Science Education in Japan. Tokyo: Japanese National Commission for UNESCO, 1968, pp. 42-49.

Furihata, Katsunobu. "Science Education in the First and Second Grades." Paper presented at the US-Japan Seminar on Science Education, Washington, D.C., 16-22 November 1985.

Gardner, Robert W.; Robey, Bryant; and Smith, Peter C. "Asian Americans: Growth, Change, and Diversity." Population Bulletin 40 (Oct. 1985).

Glass, Bentley. "The Japanese Science Education Centers." Science 154 (14 October 1966):221-228.

Grant, W. Vance and Eiden, Leo J. Digest of Education Statistics 1982. Washington, D.C.: National Center for Education Statistics (NCES 82-407), 1982.

Grayson, L.P. "Leadership or Stagnation? A Role for Technology in Mathematics, Science and Engineering Education." Engineering Education 73 (February 1983):356-366.

________. "Japan's Intellectual Challenge: The Strategy." Engineering Education 73 (December 1983):138-146.

________. "Japan's Intellectual Challenge: The System." Engineering Education 74 (January 1984):210-220.

________. "Japan's Intellectual Challenge: The Future." Engineering Education 74 (February 1984):296-305.

Harashima, Akira. "Use of Computer-Generated Animation Films in the Training of Physics." Educational Studies (International Christian University) (October 1971):143-148.

Harms, Norris C. and Yager, Robert E., ed. What Research Says to the Science Teacher. Vol. 3. Washington, D.C.: National Science Teachers Association (NSTA No. 471-14776), 1981.

Hashioka, Nobuichi. "Science Education in Lower Secondary Schools with Special References to Historical Survey on the Curriculum and Its Present Status." Education in Japan- Journal for Overseas 4 (1969):65-76.

Hueftle, Stacey J.; Rakow, Steven J.; and Welch, Wayne W. Images of Science. Science Assessment and Research Project, University of Minnesota, 1983.

Hurd, Paul DeHart. An Overview of Science Education in the United States and Selected Foreign Countries. Washington, D.C.: National Commission on Excellence in Education, 1982.

Husen, T. "Are Standards in U.S. Schools Really Lagging Behind Those in Other Countries?" Phi Delta Kappan 64 (March 1983):455-461.

Imahori, Kozo. "Out-of-School Science Activities in Japan at the Primary and Secondary School Level." The Journal of Science Education in Japan 6 (1982):57-58.

Information Processing Studies in Japan. NIER Occasional Paper 01/85. Tokyo: National Institute for Educational Research of Japan, 1985.

In-Service Training for Teachers in Japan. NIER Occasional Paper 02/85. Tokyo: National Institute for Educational Research of Japan, 1985.

Itakura, Kiyonobu and Kubo, Shunichi. "The Understanding of the Fundamental Ideas of Physics." Research Bulletin of the National Institute for Educational Research. (November 1967):1-20.

Jacobson, Willard J. National Report: U.S.A. New York: Teachers College, Columbia University, 1985.

Jacobson, Willard J. and Doran, Rodney L. "The Second International Science Study: U.S. Results." Phi Delta Kappan 66 (February 1985): 414-417.

Jacobson, Willard J. and Miller, June K. "Science Education in the United States." New York: Second International Science Study, Teachers College, Columbia University, 1984. (Duplicated).

Japan. Agency for Cultural Affairs. Outline of Education in Japan, 1970. Japan. Ministry of Education. Educational Standards in Japan-1980, 1981.

________. Science Achievement in Japan. Report of the 1957 Nationwide Survey, 1959.

________. Survey on Schools, 1984.

Japan. Ministry of Education, Research and Statistics Division. Educational Statistics, 1974.

Japan. Ministry of Education, Science and Culture. Course of Study for Elementary Schools in Japan. No. 155 (1983).

________. Course of Study for Lower Secondary Schools in Japan. No. 156 (1983).

________. Course of Study for Upper Secondary Schools in Japan. No. 163 (1983).

________. Educational Standards in Japan, 1976.

________. Mombusho, 1981.

Japan. Ministry of Education, Science and Culture, Research and Statistics Division. Japan's Modern Educational System-A History of the First Hundred Years, 1980.

Japan. Ministry of Foreign Affairs. The Japan of Today, 1982.

Japan. National Institute for Educational Research. Research Bulletin of the National Institute for Educational Research, 1980.

Japan for Educators. International Society for Educational Information, Inc. Institute for the Checking of Textbooks and Educational Materials, 1983.

The Japan-U.S. Cooperative Science Program, 1984-85. "A Study of Reasoning Skills in Junior High School Students (Grade 7-9)." n.p.: September 1985.

Japanese National Commission for UNESCO. Guidebook for the Teaching of Science in Elementary Schools in Japan, 1972.

________. Science Education in Japan-Views and Ideas, 1968.

________. Standard Teaching Materials and Equipment for Elementary and Secondary Schools in Japan, 1971.

________. Training of Science Teachers in Japan-- Present and Future.

Kagaku Kyoiku Kenkyu (Journal of Science Education in Japan) 2 (December 1978):147-242.

________. Vol. 3 (December 1979):141-194.

________. Vol. 4 (December 1980):117-198.

________. Vol. 5 (December 1981):121-206.

________. Vol. 6 (June 1982):47-88.

________. Vol. 7 (June 1983):39-84.

________. Vol. 8 (June 1984):39-164.

________. Vol. 9 (June 1985):39-92.

Kakiuchi, Yoshinobu. "Science for Science Teachers." Training of Science Teachers in Japan. Tokyo: Japanese National Commission for UNESCO (ed.), 1970, pp. 3-49.

Ken, Tobioka. "Are the Japanese Scientific?" Japan Echo, no.1, 1982, pp. 18-29.

Kirst, M.W. "Japanese Education: Its Implications for Economic Competition in the 1980s." Phi Delta Kappan 62 (June 1981): 707-708.

Klopfer, Leopold E. "Intelligent Tutoring Systems in Science Education: The Coming Generation of Computer-Based Instructional Programs." Paper presented at the US-Japan Seminar on Science Education, Washington, D.C., 16-22 November 1985.

Kobayashi, Tetsuya. Society, Schools and Progress in Japan. New York: Pergamon Press, 1976.

Kojima, Shigeo. "IEA Science Study in Japan With Special Reference to the Practical Test." Comparative Education Review 18 (June 1974): 262-267.

"Leading Professor Advocates Educating Children as World Citizens." Japan Report, no.1, 1978, pp.1-5.

Long, Theodore D. "Development of Modern Science Policy in Japan." In Columbia Essays in International Affairs: The Dean's Papers, 1965. Edited by Andrew W. Cordier. New York: Columbia University Press, 1966.

Lynn, Richard. "IQ in Japan and the U.S. Shows a Growing Disparity." Nature 297 (20 May 1982):222-223.

________. "IQ in Japan and the United States." Nature 306 (17 November 1983):292.

Mackay, Alan. "An Outsider's View of Science in Japan." Impact of Science on Society 12 (1962):177-201.

Mattheis, Floyd E.; Spooner, William E.; and Coble, Charles R. "A Study of the Logical Thinking Skills, Integrated Process Skills, and Attitudes of Junior High School Students in North Carolina." Greenville, North Carolina: East Carolina University, 1985.

Miller, June K. An Analysis of Science Curricula in the United States. New York: Second International Science Study--U.S., 1986.

Miller, June K. and Jacobson, Willard J. "The United States Science Curriculum Case Study." Second International Science Study, Teachers College, Columbia University, 1984. (Duplicated.)

Miwa, Mitsuo. "Physics Education in Upper Secondary Schools." Science Education in Japan. Tokyo: Japanese National Commission for UNESCO, 1968.

Miyake, Masao. National Report: Japan. Tokyo: National Institute for Educational Research, 1985.

________. "Type of Teacher Certificates and Qualifications Thereof." National Science Curriculum Case Studies. Tokyo: National Institute for Educational Research, 1985.

Nakagawa, Hokichi. "One Hundred Years of Elementary School Science in Japan." Education for Japan- Journal for Overseas 3 (1968):45-59.

Nagai, Michio. "Developments in the Postwar Years." Japan Quarterly 32 (January-March 1985):14-17.

Nakaji, Masayoshi. "Biology Teaching in Japan." American Biology Teacher 26 (1964):9-11.

Nakane, Chie. Japan Society. Berkeley: University of California Press, 1972.

The National Institute for Educational Research, The Second IEA Science Study: Japanese National Report. Tokyo: The National Institute for Educational Research, no. 111, (October 1985).

National Science Board Commission on Precollege Education in Mathematics, Science and Technology. Educating Americans for the 21st Century. Washington, D.C.: National Science Foundation (CPCE-NSF-04).

National Science Foundation Report. "How the U.S. Compares with Other Countries." Educational Leadership 38 (February 1981):368-370.

"NHK Educational TV Programs Offer Something for Everyone." Japan Report, no. 19, 1978, p. 6.

Nomura, Yujiro. "The Impact of Examination on Science Teaching in Japan," Journal of Science Education in Japan 4 (1980):163-166.

Office of Program Integration, Directorate for Science Education. Science Education Databook. Washington, D.C.: National Science Foundation (SE 80-3).

Ohasi, Hideo. "The System and Programme of Science Education." Science Education in Japan. Tokyo: Japanese National Commission for UNESCO, 1968, 93-105.

Okey, James R.; Wise, Kevin C.; and Burns, Joseph C. Integrated Process Skills Test II. Athens, Georgia: University of Georgia, 1982.

Oki, Michinori. "Chemistry Education in Secondary Schools." Science Education in Japan. Tokyo: Japanese National Commission for UNESCO, 1968, 29-34.

________. "Chemical Education in Schools in Japan." Paper presented at the US-Japan Seminar on Science Education, Washington, D.C., 16-22 November 1985.

Passin, Herbert. Japanese Education: A Bibliography of Material in the English Language. New York: Teachers College Press, 1970.

________. Society and Education in Japan. New York: Teachers College Bureau of Publications, 1965.

Peng, Samuel S.; Fetters, William B.; and Kolstad, Andrew J. High School and Beyond--A Longitudinal Study for the 1980's. A Capsule Description of High School Students. Washington, D.C.: National Center for Education Statistics, 1981. p.3.

Plisko, Valena White, ed. The Condition of Education, 1983 ed. Washington, D.C.: National Center for Education Statistics (NCES 83-400), 1983.

Reischauer, Edwin O. The Japanese. Cambridge, Mass.: The Belknap Press, 1977.

Roadrangka, Vantipa; Yeany, Russell H.; and Padilla, Michael J. Group Test of Logical Thinking. Athens, Georgia: University of Georgia, 1983.

Robertson, G.Ross. "Sidelights on Chemical Education in Japan." Journal of Chemical Education 34 (January 1957):44-46.

Rohlen, Thomas P. Japan's High Schools. Berkeley: University of California Press, 1983.

________. "The Japan Phenomena: An Exploratory Essay," Journal of Japanese Studies 6 (1980):207-242.

Ryu, Tae. "High School Science Teachers' Opinions on Teacher Training in University Education and on Science Education in High School." Paper presented at the US-Japan Seminar on Science Education, Washington, D.C., 16-22 November 1985.

Sakakibara, Shigeki. "The Effects of Learning in Science and Problem-Solving." Research Bulletin of the National Institute for Educational Research (1961):9-14.

Sasaki, Kiyotsuma. "Education in Zootechnical Science in Japan." Asian Affairs 5 (1961).

Sasaki, Takashi. "Outlook of Agricultural Education in Japan." Asian Affairs 5 (1961).

Schiller, Diane Profita and Walberg, Herbert J. "Japan: The Learning Society." Educational Leadership 39 (March 1982):411-412.

School Management in Japan. NIER Occasional Paper 01/84. Tokyo: National Institute for Educational Research of Japan, 1984.

The School Textbook System in Japan. NIER Occasional Paper 04/84. Tokyo: National Institute for Educational Research of Japan, 1984.

Shimada, Shigeru. "National Analysis: Japan (International Project for the Evaluation of Educational Achievement-IEA)." International Review of Education 15 (1969):163-182.

Shimahara, Nobuo K. Adaptation and Education in Japan. New York: Praeger Special Studies, 1979.

________. "Japanese Education and Its Implications for U.S. Education." Phi Delta Kappan 66 (February 1985):418-421.

________. "Socialisation for College Entrance Examinations in Japan." *Comparative Education* 14 (October 1978):253-266.

Shimozawa, John T. "The Present Status of Chemical Education in Japan." Paper presented at the US-Japan Seminar on Science Education, Washington, D.C., 16-22 November 1985.

Shinohara, Fumihiko. "Improvement of Science and Mathematics Education with the Use of Computer-Assisted Instruction (CAI) System." *Journal of Science and Mathematics Education in Southeast Asia* 4 (January 1981):42-49.

Shinoto, Yoshito. "Biology Education in Secondary Schools." *Science Education in Japan*. Tokyo: Japanese National Commission for UNESCO, 1968, pp. 35-41.

Shirai, Toshiaki. "Science Education in Elementary Schools." *Science Education in Japan*. Tokyo: Japanese National Commission for UNESCO, 1968, pp. 18-23.

Stevenson, Harold W. and Azuma, Hiroshi. "IQ in Japan and the United States." *Nature* 306 (17 November 1983):291-292.

Stevenson, Harold W.; Lee, Shin-Ying; and Stigler, James W. "Mathematics Achievement of Chinese, Japanese, and American Children." *Science* 231 (14 February 1986) pp. 693-699.

Takemura, Shigekazu. "People, Society and Science Education in Japan," in *Proceedings of U.S. - Italy Joint Seminar on Science Education for Elementary School Children*. Doris E. Hadary and Matilda Vicentini, eds. Washington, DC: The American University, 1983, pp. 153-157.

Takemura, Shigekazu. "Study on Position of Science Education in Japan." Hiroshima, Japan. Faculty of Education, Hiroshima University, 1984.

Takemura, Shigekazu, et al. "A Study of Reasoning Skills in Junior High School Students (Grade 7-9)." Hiroshima, Japan: University of Hiroshima, September 1985. (Duplicated).

Tamamushi, B. "Chemical Research and Education in Japan." *Scientific Monthly* 83 (November 1956).

The Teaching Materials System in Japan. NIER Occasional Paper 02/84. Tokyo: National Institute for Educational Research of Japan, 1984.

Teichler, Ulrich and Voss, Friedrich. *Bibliography on Japanese Education: Postwar Publications in Western Languages*. Munich: Verlag Dokumentation, 1974.

Terada, Fumiyuki. "Present Status and Future Scope of the Use of Microcomputers in Mathematics Education." Paper presented at the US-Japan Seminar on Science Education, Washington, D.C., 16-22 November 1985.

Torrance, E. Paul. "Lessons about Giftedness and Creativity From a Nation of 115 Million Overachievers." Gifted Child Quarterly 24 (Winter 1980):10-14.

Torrance, E. Paul and Sato, Saburo. "Differences in Japanese and United States Styles of Thinking." Creative Child and Adult Quarterly 4 (1979):145-151.

Troost, Kay Michael. "Science Education in Contemporary Japan." In Science Education in Global Perspective, pp. 13-66. Edited by Margarete Siebert Klein and F. James Rutherford. Boulder, Colo.: Westview Press, Inc., 1985.

________. "What Accounts for Japan's Success in Science Education?" Educational Leadership (December 1983/January 1984):26-29.

Umeno, Kunio. "General Survey of Science Education in Japan." Paper presented at the US-Japan Seminar on Science Education, Washington, D.C., 16-22 November 1985.

U.S. Department of Health, Education and Welfare. Education in Japan-A Century of Modern Development, by Ronald S. Anderson. Washington, D.C., 1975.

U.S. Congress. House Subcommittee on Science, Research and Technology. U.S. Science and Engineering Education and Manpower: Background; Supply and Demand; and Comparison with Japan, the Soviet Union, and West Germany, 98th Cong.,1st sess., 1983, by the Congressional Research Service Library of Congress.

Use of Computer in Education in Japan. NIER Occasional Paper 03/84. Tokyo: National Institute for Educational Research of Japan, 1984.

Vogel, Ezra. Japan As Number One. Cambridge, Mass.: Harvard University Press, 1978.

Walberg, Herbert J. "Scientific Literacy and Economic Productivity in International Perspective." Daedalus 112 (1983):1-28.

Waterman, Edward L. and Thompson, Stephen. "Redefining the Philosophy and Practice of Teaching High School Chemistry Laboratory." Paper presented at the US-Japan Seminar on Science Education, Washington, D.C., 16-22 November 1985.

Weiss, Iris R. Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education. Washington, D.C.: U.S. Government Printing Office (Stock No. 038-000-00364-0), 1978.

West, Robert W. "Chemical Education in Japan." Chemical and Engineering News (31 January 1966):62-68.

White, Theodore H. "The Danger from Japan." The New York Times Magazine, 28 July 1985, pp.19-59.

Yoshida, Masao. "Forestry Education." Asian Affairs 5 (1961).